NEW MILK.

"Meeleck, Come! Meeleck, Come!"
Here's New Milk from the Cow,
Which is so nice and so fine,
That the doctors do say,
It is much better than wine.

This wholesome beverage is carried all around the city by men in carts, wagons, and very large tin kettles, as we see in the cut. The cows are pastured on the Island of New-York, some along the New-Jersey shore, and large droves on Long Island. Milk sells from 4 to 6 cents per quart, delivered at our doors every morning in the winter season, and twice a day in summer.

In warm weather, one may see large churns, mounted on a wheel-barrow, pushed along by colored men, mostly from Bergen, on the Jersey shore, crying BUTTER MEE-LECK! WHITE WINE! WHITE WINE! (1830). Courtesy of A. Q.)

MILK AND DAIRY PRODUCTS

Their Composition, Food Value, Chemistry, Bacteriology and Processing

by

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PREFACE

A clear understanding of technical books and other publications pertaining to milk and milk products usually requires a knowledge of dairy science not possessed by the lay reader. The aim of this book is to give reliable information, in a non-technical manner, on the composition, nutritive value, chemistry and bacteriology of milk and milk products. Related data are given for human milk, goat's milk, and oleomargarine. Concise descriptions of the various methods used to process milk and manufacture milk products are presented. Every effort has been made to present data of recent origin and some information is given which could not be made public during the war years.

A list of publications which are recommended to the reader, should he desire to pursue the subject in more detail, is given in the appendix. The literature references have been chosen carefully and while kept at a minimum, will guide the reader to recent publications in dairy science.

It is hoped that this book will be of value and help to the progressive dairy plant executive and employee, the milk sanitarian, the dietitian, the instructor and student in agricultural and vocational schools as well as to all those who for one reason or another are interested in milk and dairy products.

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L. M. Lampert

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Chapter 1

MILK, ITS VALUE AS A FOOD AND ITS COMPOSITION

Dairy Industry

The dairy industry ranks high in importance, occupying the fourth place in the economy of the United States. According to data of the United States Department of the Interior, only the products of the iron and steel, meat and automobile industries are sources of greater wealth or income than the dairy industry.

The economic value of the dairy industry reaches beyond the wealth produced from milk and milk products. The cow is more than a milk producer. The conservation of soil fertility is of prime importance to agriculture, and experience has shown that the manure obtained by keeping a dairy herd is perhaps the most practical method to maintain soil fertility. If the farmer grows his own feed, the cow efficiently converts this to milk and returns to the soil much of the material needed to maintain fertility. In addition to her value as a source of dairy products the cow must be considered a part of our meat supply. In normal times about one-half of the beef and nearly all of the veal is obtained from dairy herds.

It is estimated that there are about 25,519,000 cows in the United States. The average output per cow is about 4,850 pounds of milk per year, but the yield of individual cows may exceed this amount greatly.[1] Yearly records of pure-bred Jersey cows show an average yield of 8,556 pounds of milk and 19,012 pounds for the highest producer. Similar records for pure-bred Holsteins show an average yearly production of 16,000 pounds of milk per cow with the highest producer yielding 38,606 pounds.

More than one-half of the milk produced in the United States originates in the northeastern quarter of the country. Wisconsin and New York furnish nearly one-fourth of the nation's milk supply.

Milk as a Food

Milk is one of the few foodstuffs consumed in its natural state and as H. C. Sherman pointed out, it is the only article of diet whose sole function in nature is to serve as a food.[2] Practically everything else we eat fulfills some other function in the animal and vegetable world. Thus most vegetables are roots or leaves of plants, fruits are parts of plants containing the seeds, and meat comes from the bodies of animals.

In Biblical times, the ideal home was in a "land flowing in milk and honey." Today a common expression used in reference to nutrition is that "milk is the most nearly perfect food." It is the one foodstuff upon which all nutritionists agree concerning its value for the growth and development of children and young animals. Not only is it the most important food during early childhood, but in one form or other it continues in our normal diet throughout life. In sickness especially, it is the one food most often called upon to sustain and nourish the body. No other single substance can serve as a complete substitute for milk in the diet. Its value was established when the first mammal nursed its young, but only in recent years have the reasons for this superiority been recognized. In these discoveries the various branches of chemistry, biology and bacteriology have had an important part. From the very beginning milk has served as a foundation for the study of nutrition.

Composition of Milk

Milk has a very complex composition. Some of its constituents, such as milk fat, milk sugar and casein are not found elsewhere, either in the body or in nature. Milk is practically the only foodstuff which contains all of the different substances known to be essential for human nutrition. Nevertheless, milk alone is not a complete food for many animals after they have grown beyond the suckling stage. Some of the essential nutrients such as iron, copper and manganese and some of the vitamins are not present in sufficient amounts or in the proper proportions to supply the requirements for complete nutrition. At birth, normal infants have a a sufficient reserve of the mentioned minerals to

last them until their diet can include foods which contain them, but certain vitamins, such as ascorbic acid and vitamin D often must be added to the infants' diet.

The composition of a food generally is given in terms of the percentage of fat, protein, carbohydrate, ash and water that it contains. The first three are the principal sources of bodily energy; ash consists of the inorganic or mineral substances present. Other very important constituents, such as vitamins and certain acids usually are present in very small amounts.

Water

About 87% of the weight of milk is water. It is, therefore, the principal constituent of milk, just as it is the chief component of most living matter. The water carries in solution milk sugar and mineral salts, such as those of sodium and potassium. Suspended in the milk are the fat, casein and certain other mineral salts, such as calcium phosphate and magnesium phosphate. It was once popularly supposed that the water in milk had some special nutritive value, but of course, this is not the case.[3] Many solid foods contain more water than does milk, as indicated in Table 1.

TABLE 1

Water Content of Some Foods (Edible Portion)

	%		%		%
Milk	87.3	Carrots	88.2	Beef Steak	70.0
Cantaloupe	95.0	Lettuce	94.8	Cottage Cheese	74.0
Watermelon	92.0	White of Egg	88.2	Salmon	65.0
Green Beans	88.9	Chicken	73.3	Ham (lean)	49.0

Carbohydrates

Foodstuffs, such as sugar and starch are known as carbohydrates and are composed of carbon, hydrogen and oxygen. The hydrogen and oxygen are present in the same ratio as they are found in water, that is, two parts of hydrogen and one part of oxygen for every part of carbon. Thus, the compounds may be regarded as a combination of the elements of water and carbon and the term carbohydrate is derived from this relationship.

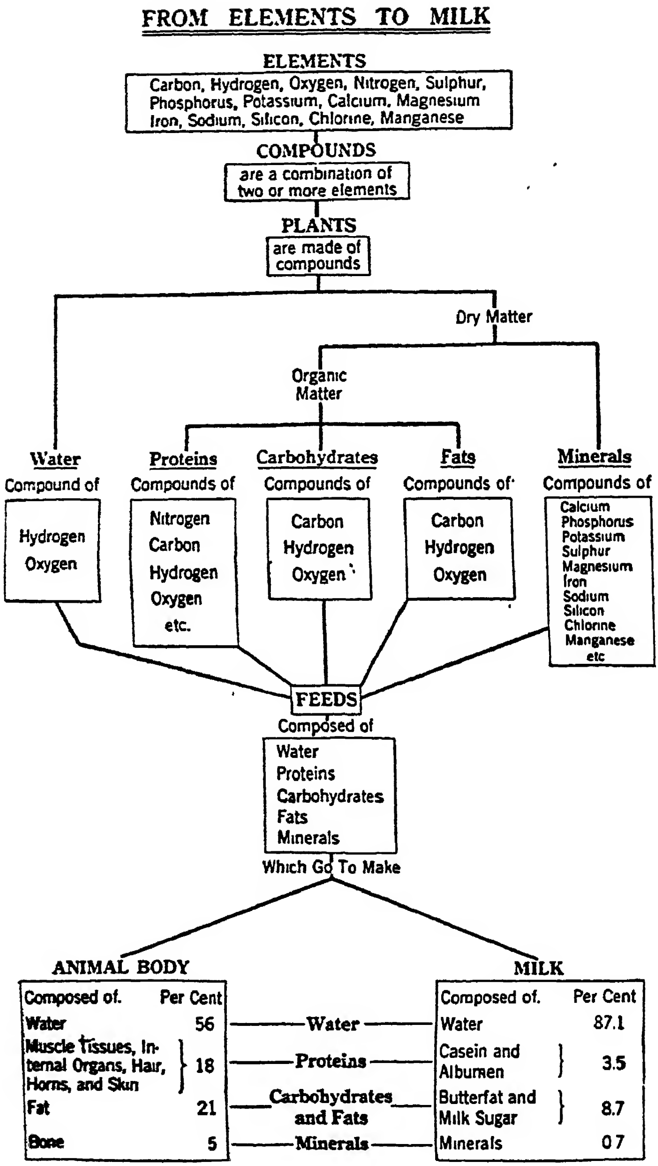


FIG. 1. Chart showing transformation of elements to feed and finally milk. (Reprinted by permission from *Dairy Cattle Feeding and Management by Henderson, Larson, and Putney*, published by John Wiley and Sons, Inc.)

The formation of carbohydrates by growing green plants is a vital process in the transfer of energy derived from the sun to animal life. It has been estimated that three-fourths of the weight of all plant material, expressed on a dry basis, is composed of carbohydrates. No other organic material is found in such widespread and large amount in the vegetable world. Carbohydrates in the form of starch or sugar are the most abundant constituents of the ordinary diet. Over one-half of the average American diet is composed of carbohydrates.

Carbohydrates are also found in products of animal origin, as for example, lactose or milk sugar in milk, glucose in honey and glycogen or *animal starch* in the liver. The body must convert all carbohydrates in the diet into glucose, the sugar found in the blood, before they can be assimilated and used in the body. Ordinarily, any surplus of glucose is converted into glycogen and stored in the liver.

About forty different kinds of sugars have been discovered, of which the best known are sucrose, which is the same as beet or cane sugar, glucose, also known as dextrose, corn or grape sugar, and lactose or milk sugar. Sucrose is a combination of glucose and levulose, which is also called fructose or fruit sugar. Lactose also is a compound of two simpler sugars, namely glucose and galactose.

Cellulose, bran and similar compounds as found in cereal grains are related to starch. These carbohydrates are not acted upon by the digestive processes and they contribute little to the nutrition. However, their presence in the diet is important after the suckling stage in order to provide the bulk needed for digestion.

The carbohydrates of milk are discussed in more detail in Chapter 2.

Fats

The fats are as important as the carbohydrates as a source of energy. The popular definition for fat is a greasy or oily substance, but this definition is of little help in a study of nutrition. To the chemist, the terms fat and oil are nearly synonymous, but ordinarily, the fats are solid and the oils liquid at room temperature. They are widespread in nature and are found in practically all vegetable and animal matter. Fats are a combination of glycerin

and fatty acids and like the carbohydrates they contain only carbon, hydrogen, and oxygen.

There are many kinds of fatty acids. Fatty acids which contain all of the hydrogen atoms with which they can combine are known as saturated fatty acids. They are found in hard fats, such as suet and tallow. Other fatty acids, found especially in the liquid oils, do not contain all the hydrogen atoms possible and these are called the unsaturated fatty acids. Under certain conditions it is possible to hydrogenate or add hydrogen to the unsaturated fatty acids. By this process, oils such as cottonseed oil, are turned into hard fats which are used in shortenings. Milk fat, probably the most complex of all fats, contains both saturated and unsaturated fatty acids.

There is little information concerning the amount of fat needed in the diet. Undoubtedly fat is necessary not only for its own nutritive qualities but also on account of the vitamins and other substances usually associated with fats from food sources. Investigations have shown that certain unsaturated fatty acids, such as linoleic acid, are needed in the diet of certain animals, probably including man.[4] In animals, at least, the absence of these fatty acids may cause kidney lesions and scaliness of the skin. It has been found that the amount of thiamine (vitamin B_1) needed by the body may be reduced if an adequate amount of fat is available in the diet.[5]

Milk fat is discussed in detail in Chapter 2.

Proteins

Proteins, which are supplied in our diet by foods, such as lean meat and cheese, are complicated organic compounds of carbon, hydrogen, oxygen and nitrogen, sometimes containing sulfur and phosphorus in addition. The word "protein" is derived from the Greek term meaning "holding first place," in reference to the early conception that the proteins were essential constituents of all animal tissues. Next to water, protein material is most abundant in the soft tissues, forming about eighteen percent of the body weight.

The proteins are made up of a large number of nitrogen-containing compounds known as *amino acids*. At least twenty-two different amino acids are known and a given protein may

contain many of these combined with each other. The amino acids have been termed the building blocks for proteins and their place in the protein structure may be compared to the use of letters in the spelling of words. Thousands of combinations of amino acids may occur just as countless combinations are possible with the letters of the alphabet in forming words. Eleven of the amino acids are considered indispensable to nutrition and must be supplied in the diet. (See table 30.) The others may be needed but, if not present in the diet, the animal body can form them from the other amino acids.

Animals, as a rule, do not build up the protein material of their bodies from simple inorganic compounds, but derive it from the protein in their food. Plants, on the other hand, can form protein directly from the material of the soil and air.

Unlike the sugars and fats, proteins seldom are found alone in a food stuff but almost always associated with fat and carbohydrates. Foodstuffs which consist principally of protein are white of egg, lean meat, and cottage cheese. Milk contains all the amino acids necessary for nutrition, whereas other foods, notably the cereals, contain proteins which lack certain important amino acids. This indicates the desirability of using milk with cereals, e.g., in baking bread, since then one foodstuff supplements the other in respect to the amino acids. Normal nutrition appears to be maintained better by proteins of animal rather than of vegetable origin.

There is no evidence that a high protein content in the diet is injurious to the kidneys or any other organ of a healthy person. Protein consumed in excess, is not stored for future use.

The most abundant protein in milk is casein, the part of milk which is coagulated by rennet to form cheese. Other proteins found in milk are milk albumin or lactalbumin, lactoglobulin and lactomucin. These are discussed in more detail in Chapter 2.

Mineral Constituents

Mineral elements essential for animal life are calcium, magnesium, potassium, sodium, phosphorus, copper, iron, iodine and chlorine and there is much evidence that manganese, zinc and several others must be included. These elements generally are considered individually but it must be stressed that mineral metabolism is not simple, and the activity within the body of one

element may depend upon the presence of other elements and compounds.

When the water of milk or other food is removed by evaporation and the dry residue is incinerated at a low red heat, there is left a white or nearly white ash which contains the mineral substances. Owing to chemical changes that occur during the ashing process, the ash contains carbonates, oxides and phosphates which are not present as such in the original food. Some of the phosphorus and sulfur compounds in the ash of milk are derived from the milk proteins; other compounds, such as the citric acid in milk, are the source of the carbonates in the ash. The ash of milk is always alkaline in reaction.

The mineral constituents of the ash of milk are given in Table 2.

TABLE 2

Average Mineral Content of Milk and of the Ash of Milk

	% in Milk	% in Ash of Milk
Potassium	0.15	21.4
Calcium	0.11	15.0
Chlorine	0.10	14.5
Phosphorus	0.07	9.9
Sodium	0.05	7.4
Magnesium	0.01	1.45
Sulfur	0.011	1.6

In addition to the minerals named above, small amounts of copper, iron, manganese, zinc, and iodine are present in milk. Traces of many other elements, such as aluminum, barium, cobalt, chromium, germanium, lithium, rubidium, silver, strontium, tin, titanium and vanadium have been found in milk.[6] Arsenic, boron and fluorine also have been detected in milk.

The importance of calcium, phosphorus, and some other minerals in milk are discussed in detail in Chapter 2.

Milk has the ability to dissolve small amounts of many metals with which it may come in contact. Copper, iron, nickel and monel metal are slightly soluble in milk whereas aluminum and stainless steel are very resistant to corrosion by it. As the acidity of milk increases so does its ability to dissolve zinc, tin solder and aluminum.

Color of Milk

The natural color of milk varies from a bluish white to a brownish yellow, depending upon the amount of fat and solids-not-fat present. The white or milky appearance is due to the colloidal dispersion of the fat globules, calcium caseinate and calcium phosphate in the milk. The size of the fat globules also somewhat influences the color, as does the breed and the feed of the cow.

The principal substances which actually impart a yellowish color to milk are the pigments carotene and riboflavin or vitamin G. The greenish-yellow color of whey is due to the presence of riboflavin; in milk this color is masked by the other constituents present. Green feed increases the carotene content of the milk and its color. It is not practical from the commercial standpoint to influence the color of milk by manipulation of the cow's feed. For example, feeding up to forty pounds of carrots per day to a cow was found to give but a slight increase in the color of her milk.

Guernsey and Jersey breeds are capable of transferring more carotene from their feeds to the milk-fat than are Holstein, Ayrshire and other breeds. The increased carotene content, higher fat content and larger fat globules in milk from Guernsey and Jersey cows are responsible for the deeper color of their milk compared with that of other breeds.

Comparison of the Milk of Various Mammals

The average composition of cow's milk, based upon a study of over 300,000 chemical analyses published by various authorities, is given in Table 3, as well as the composition of other animals.

The variation in the composition of milk of different kinds of animals seems to be related to differences in the stage of development of their young at the time of birth. Some animals, such as cows, goats, horses and sheep, are comparatively well developed and practically able to take care of themselves within a short time after birth. Others, such as rabbits, pigs, dogs and cats, are comparatively helpless at birth and much bodily development is needed before they are capable of caring for themselves. The

TABLE 3

*Average Composition of the Milk of Certain Mammals**

	Water %	Protein %	Fat %	Lactose %	Ash %
Cow	87.29	3.42	3.66	4.92	0.71
Woman	87.80	1.73	3.40	6.83	0.24
Ass	89.88	1.98	1.45	6.24	0.45
Buffalo	82.44	4.74	7.40	4.64	0.78
Camel	87.67	3.45	3.02	5.15	0.71
Cat	83.05	7.00	4.50	4.85	0.60
Dog	74.55	3.15	10.20	11.30	0.80
Elephant	85.63	3.20	3.12	7.42	0.63
Ewe	80.60	5.44	8.28	4.78	0.90
Goat	87.37	4.00	3.00	4.84	0.79
Llama	86.55	3.90	3.15	5.60	0.80
Mare	89.86	2.00	1.59	6.14	0.41
Porpoise	41.28	11.20	45.80	1.15(?)	0 57
Rabbit	68.50	12.95	13.60	2.40	2.55
Reindeer	66.10	10.15	19.80	2.50	1.45
Sow	83.60	6 15	6.00	3.20	1.05
Vixen	81.86	6.35	6.25	4.23	1.31
Whale	69.80	9.43	19.40	?	0.99
Zebu	86.20	3.0	4.8	5.3	0.70

* Compiled from various published analyses.

milk must furnish to the second group more body-building nutrients, such as protein and minerals, whereas more energy-supplying substances such as fats and carbohydrates (lactose) are needed by animals of the first group. Human milk cannot be classified in this manner, but its composition is nearest to that of the equine animals.

Estimating the Composition of Milk

Sometimes it is desirable to know the approximate composition of milk without having recourse to a chemical analysis. Studies have shown that the total-solids and the protein content of the mixed milk obtained from a number of cows closely parallels its fat content.[7] The following simple arithmetical formulas may be used to obtain the total-solids or protein content of the milk to within 0.2%:

Total solids = 7.627 + (1.346 × fat content)

Protein content = 1.597 + (0.446 × fat content)

Example: If the fat content is 3.66%, the approximate total solids content is 7.627 + (1.1346 × 3.66) or 7.627 + 4.926 = 12.55%.

Some Factors that Affect the Composition of Milk

A number of factors may influence the composition of milk. Among these are the breed and individuality of the cow, time of milking, season of the year and the cow's feed and living conditions.

Each quarter of the cow's udder may produce milk of somewhat different composition. It has been noted that the milk from the quarter first milked has the highest fat content and that drawn from the last quarter has the lowest. As the milking proceeds, the fat content of the milk increases slightly, so that the strippings, the last portions drawn, are highest in fat. The first portion obtained may contain about ~~1%~~ of fat while the strippings may have over 9%. It has been suggested that the higher fat content of the strippings probably is due to the presence of large fat globules which pass with difficulty through the milk ducts.

Effect of Breed Upon the Composition

The breed of the cow has a great influence upon the composition of her milk. The greatest difference is found in the fat content of the milk. Guernsey and Jersey cows yield milk of high fat content whereas that of the Holstein and Ayrshire breeds is relatively low in fat. The lactose and ash content show less variation. Table 4 shows the range and average composition of milk from different breeds of cows. The breed has also an influence upon the color of the milk.

The protein and lactose content of the milk of an individual cow varies but little from one regular milking to the next.

Effect of the Time of Milking

The *time of milking* has some affect upon the composition. If an equal length of time elapses between the morning and evening milkings there is no consistent difference, but if the cow is milked in the morning and then late in the evening, the morning milk may

TABLE 4

Range (a) and Average Percentage Composition (b) of Milk of Different Breeds of Cows

Breed	Water Min.	Water Max.	Water Av.	Fat Min.	Fat Max.	Fat Av.	Protein Min.	Protein Max.	Protein Av.	Lactose Min.	Lactose Max.	Lactose Av.	Ash Min.	Ash Max.	Ash Av.	Total Solids Av.
Ayrshire	84.24	89.44	87.20	2.92	5.66	3.85	2.92	4.58	3.46	2.11	6.11	4.80	0.58	0.85	0.69	12.80
Brown Swiss .	...	...	86.59	...	...	4.01	...	...	3.63	..	...	5.04	...	. .	0.73	13.41
Devon	...	...	86.26	...	...	5.07	...	...	4.15	...	...	3.76	...	...	0.76	13.74
Guernsey	82.12	87.93	85.31	3.65	7.66	5.00	2.65	5.45	3.98	3.57	5.78	4.96	0.60	0.85	0.75	14.69
Holstein	82.38	89.28	88.07	2.72	6.00	3.45	2.44	6.48	3.15	3.96	5.71	4.65	0.56	0.86	0.68	11.93
Jersey	82.32	89.04	85.35	3.28	8.37	5.14	2.98	5.83	3.84	2.73	5.66	4.92	0.57	0.82	0.75	14.65
Short Horn...	...	...	87.32	...	...	3.72	...	...	3.32	...	...	4.92	...	...	0.72	12.68

Min. = Minimum; Max. = Maximum; Av. = Average.

(a) Overman, Sanmann and Wright, *Ill. Agr Expt. Sta. Bull.* 325, 1929.

(b) Various authorities.

contain from 0.5 to 3.0% more fat. If the cow is milked three times a day, the noon milking usually shows the highest fat content.

Effect of Age

The *age* of the cow has a slight but definite effect on the composition of her milk. Studies made in England [8] show that over a period of about ten years the fat content decreased about 0.2% and the solids-not-fat content about 0.5%.

Effect of Disease

The milk from a diseased cow may vary greatly from normal milk. Generally there is an increase in the fat and salt content and the lactose content is diminished. Milk from a diseased udder tends to approach the composition of the cow's blood-serum, especially, in that its albumin content is increased.

Effect of Feed

The yield and composition of milk are affected by the amount and kind of feed consumed by the cow. Overfeeding does not increase the normal flow of milk, but underfeeding has a pronounced effect. A great decrease from the normal ration will cause a rise in the fat content but the quantity of milk produced is materially decreased. Considerable variation may occur in the protein and carbohydrate content of the cow's feed without having much effect upon the composition of the milk, but the total output will be reduced if these components of the feed are reduced materially.

Fat-rich feed or the inclusion of various fats or oils in the cow's diet has a definite effect upon yield, composition and properties of milk fat. Some fatty acids which are not normal constituents of milk fat may appear in it if they are present in the feed. The presence of certain fish oils, such as menhaden and codliver oil in the feed will cause the fat content of the milk to decrease markedly. In general, the feeding of fat-rich foods is not a practical way to increase the fat content of the milk.

The mineral content of milk is fairly constant and is influenced

but little by the feed. A deficiency of calcium and phosphorus in the diet is not reflected in the composition of the milk since the cow will draw upon her own skeleton to furnish these elements. In this way, nature gives the calf sufficient minerals from its mother to insure normal bone growth. Experiments have shown that iron, copper, calcium and phosphorus cannot be added to the milk by inclusion in the feed. The iodine content can be increased appreciably in the milk by feeding iodine compounds, but there is some evidence that this tends to lower the yield and fat content of the milk.

The amount of certain vitamins in the milk may be increased greatly by feeding substances rich in these vitamins. The subject is more fully discussed in the chapter on vitamins.

Energy Value of Milk

The utilization of food by the body is essentially a chemical process and may be compared to the consumption of fuel by an engine. The body uses a complicated process of combusion, since the fuel is not only needed to run the body engine but also to become part of the body itself. Fats are the most efficient sources of energy; they furnish nearly twice the amount of energy per unit of weight as do the carbohydrates or proteins.

Whether it is produced by an engine or by the body, energy may be measured in terms of heat units and usually is so expressed in studies of food values. The unit commonly used is the large calorie, which is equivalent to the amount of heat needed to raise the temperature of a kilogram (2.2 pounds) of water from 15° to 16°C. This is practically the same amount of heat needed to raise the temperature of four pounds of water one degree Fahrenheit. Until the discovery of vitamins, much stress was placed upon the number of calories contained in the diet, and complete and adequate nutrition was thought to depend upon whether or not the diet furnished sufficient calories. Today it is known that other factors must be considered too, but the calories are just as important as ever.

Certain factors control the exact energy requirements of an individual. For example, a man of large stature needs more food than does a person of small stature. Children need food energy for growth as well as for the maintenance of bodily health and

for supplying the energy for their activities. The energy requirements of an individual tend to decline with advancing age. At absolute rest, a person needs only enough energy for the work of the necessary life processes. This usually is called basal energy and averages about seventy calories per hour for the average male adult. It corresponds roughly to the energy needed to keep two forty-watt electric lamps burning. During sleep the energy requirement is somewhat less. Since women average about four-fifths the size of men, their basal energy requirement is about fifty-five calories per hour.

The amount of energy which various foods yield to the body has been studied in great detail. The values found by the American scientists, Atwater and Bryant, about 40 years ago, are generally used. The accepted values are as follows:

Carbohydrates	yield 4 calories per gram or 0.141 per ounce.
Proteins	yield 4 calories per gram or 0.141 per ounce.
Fats	yield 9 calories per gram or 0.317 per ounce.

By means of these factors, the energy value of any foodstuff of known composition may be calculated. As an example, the calorific value of milk of average composition can be calculated from the data in Table 3. The mineral matter and water have no calorific value. Since the composition is expressed in percentage, there are present 3.66 grams of fat, 3.42 grams of protein and 4.92 grams of lactose per hundred grams of milk. The calorific values then are:

3.66×9 calories—32.94 calories from the fat
3.42×4 calories—13.68 calories from the protein
4.92×4 calories—19.68 calories from the carbohydrate

66.30 calories for 100 grams milk

One pint of milk of average composition weighing 487 grams will furnish about 323 calories. If the fat content is higher than 3.66%, the calorific value will be materially greater.

If only the fat content is known, the calorific value of milk may be estimated by means of the following formula:

Calories per pint $= 52.65 \times$ (percentage of fat $+ 2.42$)

Compared to some other foods, milk has a low energy value owing to the large amount of water present. As shown, a pint of milk, which contains about 14 ounces of water, supplies about 320 calories whereas a pound of bread, which contains about

$5\frac{7}{10}$ ounces of water, supplies about 1180 calories. If all the water were evaporated from the milk and if the bread also were water-free, the figures would be 2446 calories per pound of dry milk and 1829 calories for the dry bread.

The fat supplies nearly one-half of the total calories in milk; the lactose about 25% and the protein about 21%. Fat ordinarily constitutes about 4% of the weight of milk; in this 4% is concentrated nearly one-half of the total calorific value of milk.

CHAPTER 2

PROPERTIES AND USES OF SOME MILK CONSTITUENTS

Milk Fat

Milk fat, which often is called *butter fat,* differs from other fats of animal origin in the large number of different fatty acids present, especially those of comparatively simple composition, such as butyric, caproic, and capric acids. These acids have a strong and characteristic odor and their liberation during decomposition of milk fat is the cause of rancid flavor and odor in milk products.

The analytical chemistry for the detection of foreign fats in butter makes use of the fact that the proportion of these fatty acids in milk fat is fairly constant. Other fats and oleomargarine contain little or none of these fatty acids, and a deficiency of certain fatty acids, such as those named above, is an indication that the butter is adulterated with a foreign fat.[9]

The fat in milk is present in the form of myriads of small, individual globules; about 2000 billion fat globules may be found in a pint of milk. It is evident that the fat globules are very small; smaller in fact, than some bacteria. The globules vary from about one-tenth to twenty microns in diameter, and average about three microns in diameter. Bacteria often are from two to five microns long (one micron is approximately 1/25,000 of an inch). Milk of high fat content usually contains globules of more than average size. Each fat globule is surrounded by a film or skin of protein, which prevents it from combining with others to form a larger globule or mass of fat.[10, 32] When milk or cream is churned, the mechanical agitation to which the globules are subjected, causes the film to break. This enables the fat in the individual globules to combine to form a mass of butter which separates from the buttermilk.

It has been found that milk fat is more easily digested and

larger amounts of it can be absorbed without producing a digestive disturbance than any other common edible fat. Milk is coagulated in the stomach and the fat is retained within the curd particles, thus it cannot form large masses of fat which would be difficult to digest.

Most common edible fats of low melting point have about the same degree of digestibility.[11] About 97% of the milk fat ingested is utilized by the body; for lard, beef fat, and mutton fat the figures are 97, 93, and 88% respectively. Mutton fat has a relatively high melting point.

Lecithin and Cholesterol

Associated with the fat of milk are related compounds known as phospholipids and sterols. The phospholipids may be called *phosphorized fats* since a part of the fatty acids ordinarily present is replaced by phosphoric acid and a nitrogenous base. One of the best known of the phospholipids is *lecithin* which is found in milk fat, egg yolk and soybeans. It is present in the tissues of the nervous system of animals and is also found in nearly all vegetables. The nitrogenous base in lecithin is known as *choline,* a substance which also is part of the vitamin B complex and important for growth and the metabolism of fat. About 0.16% of lecithin is found in milk and about 0.25% in butter.[12]

Lecithin, usually derived from egg yolk or soybeans, is used in the manufacture of mayonnaise, chocolate, oleomargarine and other fatty foodstuffs, since it helps to emulsify the fat with the aqueous portion of the product. When milk or cream is churned, much of the lecithin is retained by the buttermilk.

The sterols are wax-like substances which chemists classify as solid alcohols. *Cholesterol,* the principal sterol found in milk, is also an important constituent of the body and especially of nervous tissue. Foods which contain appreciable amounts of cholesterol are fats and oils of animal origin, egg yolk, liver and butter. Milk contains about 0.015% cholesterol and pure, dry milk fat about 0.35%.[13, 14]

The finding that cancerous tissue may contain more cholesterol than does healthy tissue has been used by some food faddists as a claim that milk in the diet is a cause of cancer. This statement has no basis, scientific or otherwise. Egg yolk contains, per unit

of weight, much more cholesterol than milk or butter, yet eggs are accepted as good food by everyone.

Phytosterol, a sterol very similar to cholesterol, is found in vegetable fats and oils. It is not found in animal tissues and the phytosterol in a cow's feed does not pass into the milk fat. Simple tests are known which distinguish between phytosterol and cholesterol. They enable the chemist to detect the presence of vegetable fats as an adulterant in butter.[15]

Lactose

Lactose is found only in milk. It is generally prepared from the whey obtained as a by-product in the manufacture of cheese and casein. The potential supply is over 400 million pounds per year, but of this vast amount only about four million pounds are prepared.

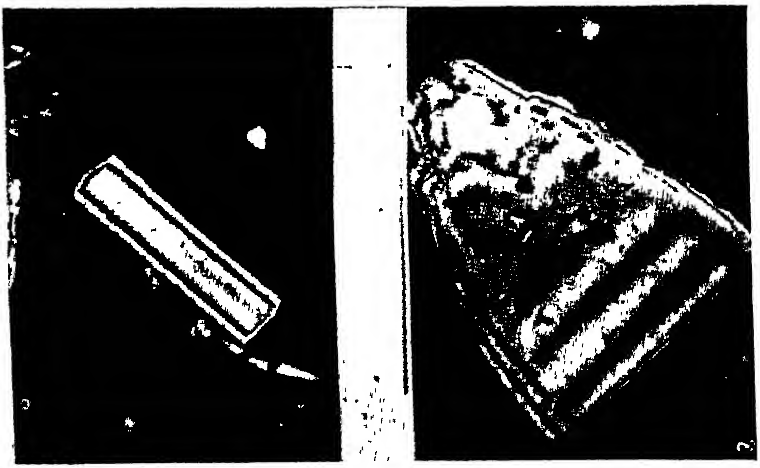
Next to its water content, the largest single constituent of cow's milk is lactose or milk sugar. Traces of other sugars may be present in milk. About 0.1% of glucose has been found in cow's milk [16] and traces of two other sugars, *gynolactose* and *allolactose*, have been found in mother's milk.[17] Lactose occurs in the milk of all land animals and probably in the milk of all mammals. Cow's milk contains an average of 4.92% of lactose, but the amount may vary from as little as 2.4% to 6.1% (see Table 4).

In the preparation of lactose, whey is heated nearly to the boiling point and then lime is added. The milk albumin and a large part of the mineral matter separate from the whey and are filtered off. The remaining liquid is concentrated by evaporation of the water until it contains about 80% of total solids and then is cooled, with constant agitation, until crystallization of the milk sugar is complete. The crystals of lactose are separated from the liquid in a sugar centrifuge and washed sparingly with cold water.[18] Lactose made in this manner is known as *alpha-lactose* and its solubility in water is only 17.8 parts per hundred at 77°F.

Another form of lactose, *beta-lactose*, is made commercially by careful heat control of the drying procedure.[18] Since it is sweeter and much more soluble than alpha-lactose, beta-lactose is being increasingly used in diets and baby foods.

Milk sugar forms easily a supersaturated solution in water. In such a solution more lactose is present than is normally able

to remain dissolved and, when a small crystal of lactose is added, the excess amount of lactose in the solution separates in crystal form. The formation of lactose crystals sometimes causes trouble for the manufacturer of ice cream and sweetened condensed milk. These products contain so much lactose that it may separate from the product in the form of crystals, giving rise to a condition known as *sandiness*, since the crystals are hard and very slowly soluble.



a b

FIG 2. *Lactose Crystals* (313 X)

(a) Beta-lactose crystal.
(b) Typical axe-shaped crystal of alpha-lactose. *(Courtesy of Missouri Agr. Exp Station, Bull. 373.)*

Uses of Lactose

Although a vast amount of lactose is consumed in the form of milk and milk products, the sugar itself has only few industrial applications. Much milk sugar is used as a constituent of infant foods and medicinal products. Physicians prescribe lactose for the modification of cow's milk for infant feeding, in order to bring its composition closer to that of human milk. It has been suggested that since galactose (which is present in lactose) is needed in the early stages of brain formation, milk sugar should be added to the infant's diet, rather than other sugars.[10]

Large amounts of lactose are needed as an ingredient of the medium employed for the growth of the molds in the manufacture of penicillin. Pharmacists use the sugar as a base for pills and tablets since a hard, compact mass is formed when the sugar is slightly moistened and then compressed. Confectioners use lactose in some fondants and tablet-like candies. Lactose has been used as an ingredient of mixtures for making smoke screens for military use.

Methods have been perfected for the continuous manufacture of lactic acid by the fermentation of lactose in whey.[20, 21] The uses of lactic acid are limited. Lactic acid is employed in the manufacture of medicinal products, chemicals and as a substitute for acetic and citric acids in the preparation of pickles and other foodstuffs. An increasing amount of lactic acid is used in the manufacture of certain types of plastics.[22] During World War II, lactic acid was used as an ingredient of a fire-quenching solution to control the fire started inside of tanks by enemy shells.

Nutritional Value of Lactose

No authoritative study concerning the nutritional value of lactose has been made. In grown animals it does not have the fattening effect of most other sugars and there is some evidence to show that lactose stimulates the growth of small animals.[23] When fed to rats, they lived longer and grew more rapidly than those fed sucrose.[24]

Some investigators have observed that fat may be needed for the efficient utilization of lactose. Rats fed no food other than whole milk do not eliminate lactose through the kidneys, but do so when put on a diet of skim milk.[25] The addition to skim milk of three or four percent of a fat such as butter or lard, is sufficient to enable the animal to make use of the lactose in its diet. It should be emphasized that animal feeding experiments add to our knowledge of dietary factors, but that the diets used are very abnormal and bear little relation to the ordinary balanced diet used by human beings.

Owing to the slowness with which it is broken down in the digestive process, some unchanged lactose reaches the large intestine. Lactose is an excellent food for acid-forming bacteria and is, therefore, used in acidophilus milk therapy to assist in the

maintenance of these organisms in the colon. Acidophilus milk is described in Chapter 10.

Casein

In general commercial practice, casein is obtained from skim milk by the addition of a dilute solution of acid, usually either hydrochloric or sulfuric acid. In another process, casein is obtained by the action of lactic acid developed directly in the milk by the action of bacteria.[26] After the casein is precipitated, the mixture is warmed and the whey is then removed from the curd. The separated curd is washed with water in order to remove as much as possible of the acid, lactose and milk salts retained by the casein. The casein then is dried and ground to the desired size.

Casein may also be obtained from milk by the action of rennet. Casein separated from milk in this manner is known, technically, as paracasein, but its composition is the same as that obtained by the action of acid.

In 1941, about 47 million pounds of casein were manufactured in the United States. By 1945, production had dropped to about 12 million pounds because the milk supply had been diverted to food uses. The total consumption in 1941 was about 89 million pounds, of which more than one-half was imported from Argentina. About one-half of the casein was used for paper coating, twenty percent for adhesives, eight percent was used in the manufacture of paints and plastics and about four percent in the manufacture of artificial fibers. The bulk of the American production comes from Wisconsin, California, New York and Minnesota.

Casein as a Food

Casein, as such, is not used as a food product, except in experimental diets for animals and as a constituent of certain health foods. Casein also is used in the preparation of media used in bacteriological work. Ammonium and calcium caseinates used in foodstuffs for special diets are sold under various trade names. One brand of calcium caseinate (Casec) is stated to have the following composition—Protein 88.0%; Fat 2.0%; Water 5.5%; Calcium Oxide 2.5%; Phosphoric Oxide 1.4%.

Twenty-one amino acids have been isolated from casein. In

its nutritive value casein compares favorably to the proteins of meat but it is low in the essential amino acids cystine and methionine. Casein is a valuable contributor of phosphorus to the diet since it contains 0.71% of the element.

Industrial Uses of Casein

Casein Glues, Cements and Adhesives

These preparations may be considered to be solutions of casein in an alkaline solvent. Casein glues made with the addition of calcium compounds become water-repellent upon drying. The alkaline solvent used may be lime, sodium carbonate, borax or an organic base such as triethanolamine.

Paper Coating

The principal commercial use of casein is in the manufacture of paper coating. This, essentially, is a glue made from casein and mixed with clay and mineral pigments. The casein binds the clay and other materials to the paper. Coated paper has a superior printing surface which takes ink more evenly and gives much better picture and color reproduction than uncoated paper.

Casein Paints and Calcimines

These materials are essentially a solution of a casein glue with a filler and pigment. Generally, ground casein and lime are used, especially in water paints for outdoor application. Common fillers are china clay, chalk and kaolin. When dry, the compound of casein and lime is practically insoluble in water. Poster paints and water colors are often made with casein.

Plastics

A plastic material may be made from casein. Usually rennet casein is used, but sometimes acid-precipitated casein is employed in the manufacture of transparent and translucent plastics. The casein is ground and small amounts of water are added, together with any desired dye, pigment or filler. The mixture is fed to a screw operated extruding machine where it is forced through resistance screens. Under the heat and pressure applied, the mass becomes plastic as it emerges from the nozzle of the machine in the form of rods. If sheets are desired, the extruded rods are

placed in molds and formed into sheets by hydraulic pressure. The rods and pressed sheets are immersed in a weak solution of formaldehyde. This renders the plastic insoluble and hardens it. After the curing process the material is dried, the sheets are straightened and the rods are straightened and ground to the desired diameter. The finished material is not moldable but is fabricated by machining, grinding or carving. The principal uses of casein plastics are in the manufacture of buttons, buckles, ornaments, and costume jewelry.[27, 28]

Textiles

A method for making a fiber out of casein was developed about fifty years ago, but these early developments were not successful because the fibers soon became brittle. The first successful casein fiber was made in Italy about 1935 and it was manufactured commercially in several European countries under the name of *Lanitol* or *Lactofil*.

Research workers in the United States devised other methods for making casein fibers.[29, 30] One such fiber is manufactured under the name of *Aralac*. In general, for the manufacture of such casein fibers the casein is ground into powder form and dissolved in a solution of caustic soda. The concentration is carefully adjusted and chemical agents, such as sodium and aluminum sulfate and sulfuric acid, are added to help in maintaining the flexibility of the finished fiber. Steps in the manufacture of Aralac are shown in Figures 3 and 4.

The solution is forced through tiny holes or spinnerets very similar to those used in the manufacture of rayon. The fine stream leaving the spinneret enters a tank which contains a solution of formaldehyde, sodium chloride and other chemicals. The casein is precipitated as it strikes this solution, and is hardened and formed into a fiber which can be spun. Bristles for paint brushes have also been made from casein.[31]

The chemical composition of the casein fiber is very similar to that of wool, except that wool contains about five times as much sulfur as does casein. The casein fiber resembles wool in outward appearance but unlike wool, which has a scaly surface, the casein fiber is smooth. An interesting feature of artificial wool made from casein is that it is not attacked by moths. Considerable

FIG. 3. *Casein Fiber Spinneret in Action*

Liquefied casein enters the spinneret through the pipe, lower left, and is forced through thousands of tiny holes in the spinneret. The material leaving the top of the spinneret actually consists of thousands of strands of fiber. *(Courtesy of Aralac, Inc.)*

amounts of casein fiber are used to replace a part of the rabbit fur employed in the manufacture of felt hats.

Other Uses of Casein

Casein is used as an adhesive in a number of insecticidal and fungicidal sprays. Ground casein and lime are combined to form

Fig. 4. *Spinning Box for Casein Fiber*

Four spinnerets are concealed under the foam in the spinning box in which the fibers are chemically treated. The hand indicates the relative size of the strips of fibers. Many other processes must be undergone before the fiber is ready for use. *(Courtesy of Aralac, Inc.)*

calcium caseinate, which, after mixing with water and the insecticidal material, is sprayed on fruit or foliage. The casein compound favors a complete and even coverage of the material that is sprayed. A similar compound of casein is used in the preparation of emulsified oil sprays.

Compounds of casein with arsenic, iron, mercury, iodine and silver have been used in medicine.

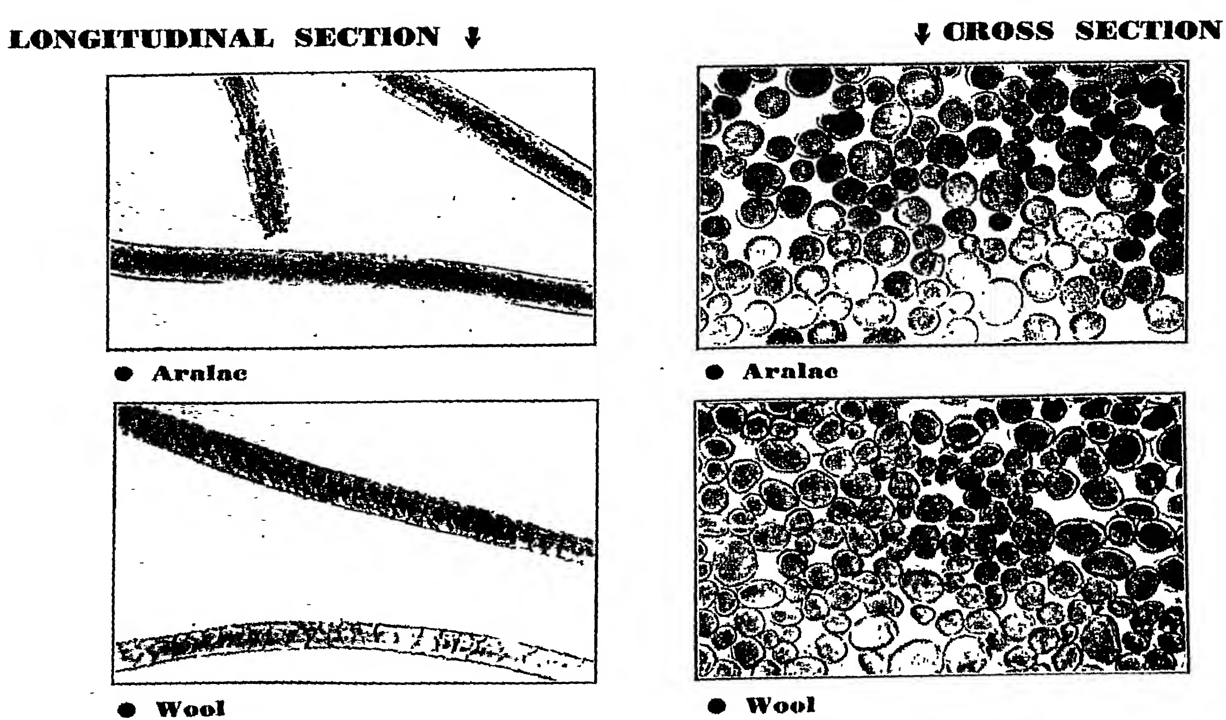


FIG. 5. *Photomicrograph of Wool and Casein Fibers* (Magnification 500 X)
Top: Casein Fiber. Bottom: Wool. *(Courtesy of Aralac, Inc.)*

Lactalbumin

Next to casein, lactalbumin or milk albumin, is the protein occurring in the largest amount in milk. About ½ percent of the weight of milk consists of lactalbumin. It is very similar to but not identical with the albumin present in blood serum. Like the albumin found in the white of egg, lactalbumin is coagulated easily by heat. A small amount is probably coagulated when milk is pasteurized and nearly one-third of the lactalbumin is coagulated when milk is heated to 160°F. for thirty minutes. Unlike casein, lactalbumin is not coagulated by rennin.

When casein is removed from milk, either by the use of acid or rennet, lactalbumin and other milk proteins remain in the whey. Sometimes, after the manufacture of cheese, the whey is heated to coagulate the lactalbumin present. The coagulated material is gathered and formed into a cheese-like product, known by various names as *ricotta, ziger* and *mysost*. It is used by many people, especially the Italians and Scandinavians.

Lactoglobulin and Other Milk Proteins

Milk contains about 0.05% of a protein known as lactoglobulin, which is identical with a gobulin found in blood. *Colostrum,* the secretion from the mammary gland for a few days after birth of the calf, is rich in globulin and may contain as much as fifteen percent of it. Lactoglobulin is very rich in the amino acid *lysine,* which is important for growth.

The presence of a protein membrane around the fat globule in milk was long suspected since fat is not easily extracted from milk by fat solvents nor do the globules coalesce or combine with each other to form large masses of fat. It has been found that the fat globules actually are surrounded by a skin or film of protein material, reported to be about ten millimicrons or about 1/2,500,000 inch thick.[10, 32] This film, sometimes called *lactomucin,* is rich in phosphorus compounds. A large portion of the membrane is removed from the fat and left in the buttermilk when milk or cream is churned.

Traces of nitrogenous materials, not of proteinic nature, are found in milk.[33] They are probably by-products or left-overs

formed during the manufacture of milk in the udder. When milk is heated, and especially if it is boiled, additional non-protein nitrogenous material is formed, probably by decomposition of milk proteins.

Milk Minerals

Calcium

About 1.6% of the weight of the adult human body is calcium. It forms a larger portion of the body weight than any other inorganic substance, except water. About 85% of the ash of the skeleton consists of tri-calcium phosphate, the form in which a great part of the calcium is also present in milk. Physiologists claim that 99% of the lime in the body is found in the bones and teeth, the other 1% in the body fluids, nerves, heart and muscles, where it assists in the proper maintenance of body functions. It also has an influence upon the clotting power of the blood.

The exact amount of calcium needed in the diet of the adult is not known, but generally it is held that the American diet is deficient in foods rich in calcium. It has been estimated that the average person should consume about one-half gram of calcium per day, and, to be on the safe side, the diet should contain at least 0.7 gram.[2] The requirement for pregnant and nursing women is about 1.5 grams per day.[34] At birth, the child has no reserve of calcium and it is essential that calcium be supplied in an adequate amount to meet the needs of the rapid growth period. A deficiency of calcium leads to a number of physical ailments, such as poor development of the bones and teeth, rickets, weakness of the heart muscles, and general irritability and nervousness. There is some evidence to show that the body does not need as large a supply of iron as otherwise might be needed, if the calcium supply is ample.[35]

Milk contains more calcium per unit of dry matter than most other foodstuffs. With the exception of the leafy vegetables, no other food has sufficient calcium to meet the dietary requirements. In general, children do not utilize the calcium of vegetables as well as that from milk, whereas the reverse appears to hold true for adults.[36] The utilization of calcium by the body is related to the intake of phosphorus and vitamin D.

The calcium content of milk is remarkably constant. Removal of the mineral from the diet of the cow does not alter the calcium content of her milk, since she will then transfer the element from her skeleton to the milk in order to maintain its normal calcium content. By this action, nature provides the suckling calf with a source of calcium needed to build its bones. It is impossible to increase the calcium content of the milk by feeding the cow a diet high in this mineral.

It generally is stated that one quart of milk per day will supply the calcium requirement of a growing child. According to one investigator, a normal child, between the age of three and five years, will retain as much calcium from one pint of milk per day as from two pints, provided that the diet also furnishes enough protein, phosphorus and vitamins.[37] There also is some evidence that the addition of orange juice to milk favors the retention of more calcium by the body than would otherwise occur. It has been shown further that, for the immature animal at least, the lactose of the milk, has a beneficial influence on the utilization of calcium and phosphorus.[38]

When milk is pasteurized or boiled, ten to twenty percent of the calcium becomes less available to the body, as measured by feeding experiments with rats. Since cow's milk contains more calcium than human milk, this loss is not important so far as child nutrition is concerned. According to Sherman, milk is a richer source of calcium than a saturated solution of lime water.[2] The comparative values of dairy products as sources of calcium are given in Table 38.

Phosphorus

Phosphorus is an important constituent of all the body cells. Relatively large amounts of it are present in the brain and nervous tissues. In combination with calcium, it is found in the bones. It has been estimated that the adult human skeleton contains about 600 grams of phosphorus, the muscles about 56 grams and the brain and nervous tissue about 5 grams. The average normal adult needs about 0.88 grams of phosphorus per day; the growing child about 1.3 grams. The requirement during pregnancy and lactation are similar to those for calcium.[2]

Magnesium

Magnesium is essential for all living tissue. About 71% of the body's content is found in the bones. Magnesium takes part in the chemical changes that occur in carbohydrate utilization by the body and there is some evidence that it also aids in the utilization of fats. The average adult consumes about 0.27 gram of magnesium per day.[2] A deficiency of the mineral leads to digestive disturbances, retarded growth and impairment of the nervous system.

Sodium, Potassium and Chlorine

Although potassium is very similar to sodium in its chemical properties, it cannot replace sodium in the animal body. Herbivorous animals, including the cow, obtain more potassium than sodium from their usual feed. To make up for this lack of sodium, the element is supplied to the cattle in the form of salt blocks.

Sodium is present in larger amount in the blood and body fluids but potassium predominates in the soft body tissues, blood corpuscles and milk. The adult body needs about 0.06 gram of potassium per day and the infant about 0.07. Sodium is usually available in more than sufficient quantities since it is used in the form of sodium chloride or table salt in food.

Probably all of the chlorine in cow's milk is combined with sodium. In mother's milk there is more chlorine than sodium and apparently in this case, some of the chlorine is combined with calcium. The average sodium chloride content of cows' milk is 0.16%, and the normal range is between 0.15 and 0.18%. Milk from cows with diseased udders usually has a high salt content and tastes salty. In milk from cows with mastitis, the sodium chloride content may reach nearly 0.3%. A close relationship has been observed to exist between the chlorine content and the amount of lactose in milk. If, due to disease, the amount of lactose is decreased, the loss is compensated for by an increase in the chloride content.[39]

Iron

Iron is essential for the formation of hemoglobin, the pigment to which blood owes its red color. About three grams or two-thirds of all the iron in the body is contained in the hemoglobin. At birth, the body contains a sufficiently large reserve of iron to supply the needs of the infant until the milk diet can be supplemented with other sources of the element.

The form of iron in the diet is important since the body can only assimilate the soluble form.[40] Some foodstuffs comparatively rich in iron are nevertheless poor sources of it for nutritional purposes since the iron is present in a non-soluble form. For example, in spinach only about one-fourth of its iron content is available for the body whereas in eggs and milk all of the iron is in a readily utilizable form. Many simple inorganic salts of iron are assimilated by the body and such salts may be used to supply the mineral if the diet needs a supplementary amount of iron.

The normal adult man needs about 10 to 12 milligrams of iron per day; women during pregnancy probably require about 17 milligrams per day. Children need somewhat less than adults. A nutritional form of anemia results if the iron intake is too low or if the iron is not properly assimilated. A diet rich in calcium and of only moderate iron content is able to maintain the normal composition of the blood.[35] If the calcium intake is reduced, anemia may occur, even though the diet contains the same amount of iron.

The amount of iron in milk is small and varies between 0.2 and 0.5 parts per million parts of milk.[41] Higher values have been found but it is believed that an increased iron content is due to contamination of the milk by contact with iron equipment. Milk can dissolve appreciable amounts of iron, and if increased amounts are present they may cause the milk to develop a disagreeable flavor.

Copper

Nutritionists state that the normal adult needs about three milligrams of copper per day; the child from 1.5 to 2.5 milli-

grams. Copper is essential to nutrition in that it takes part in the utilization of iron in the formation of hemoglobin.[42] A deficiency of copper is rarely found in the average diet. Foods that contain iron usually are also good sources of copper. The infant is born with a large reserve of copper in its liver for use during the first few months of life until other foods are added to the milk diet.

Traces of copper are found in milk and in many plant and animal tissues. The copper content of milk varies from about 0.10 to 0.20 parts per million. Milk may dissolve small amounts of copper during its various processing procedures since much dairy equipment still in use is made of tinned copper and the tin may have worn off in some places. As little as 1.5 parts of copper per million parts of milk sometimes is sufficient to cause a change in the flavor of milk. The presence of copper in milk has been found to reduce its ascorbic acid (vitamin C) content appreciably.

Iodine

Iodine is an essential ingredient of thyroxin, a substance secreted by the thyroid gland. This secretion has a powerful effect on the body. It is necessary for the regulation of growth and utilization of energy and many other important physiological functions. Foodstuffs vary greatly in their iodine content. Since the iodine is derived either from the soil or water, the most iodine will be found in foodstuffs obtained from regions near the sea or where the soil is rich in the element.

In a large part of the United States, reaching from the Appalachian Mountains in the East, along the Great Lakes and the northern states westward to the Pacific Coast, the soil and water is poor in iodine. Foodstuff grown in this region contains very little iodine. If such foods were the sole diet of a person he would soon show symptoms of iodine deficiency, such as sensitiveness to infections, enlarged thyroid gland or goiter and lowered mental activity. The use of iodized salt is one of the methods used to combat a deficiency of iodine in the diet.

The adult body contains about twenty-five milligrams of iodine, about three-fifths of which is in the thyroid gland. The daily requirement is estimated to be between 0.05 and 0.1 milligram. Children need more than the adult, the daily requirement being about three times that of the adult.

Iodine is present in milk, but in very small and widely varying amounts. It is one of the few substances which are transmitted easily from the feed into the milk. Ordinarily, milk may contain from 0.04 to 0.06 parts of iodine per million parts of milk, a very small amount. Cows in regions near the sea shore give milk which is relatively rich in iodine, containing up to two parts per million parts of milk. Milk from cows that have been fed substances that contain iodine may contain up to fourteen parts of it per million of milk.[13, 14]

Manganese

This element is a normal constituent of milk, but only traces of it are present, usually between 0.02 to 0.1 part per million.[2] The function of manganese in the diet is not known. Some authorities believe that it is connected with the utilization of iron. In experiments on rats, a lack of manganese in the diet leads to sterility in the males and inability of the female to raise their offspring. A leg-bone deformity in chickens, known as perosis or slipped tendon, is associated with a deficiency of manganese in their diet. This suggests that traces of the element may be needed for proper bone development.

Zinc

Zinc is present in many body tissues, especially the reproductive organs and the thyroid gland. Rats fed a diet low in zinc show a marked decrease in their rate of growth and their coat of hair does not develop normally.

Milk contains from three to four parts per million of zinc.[45] The metal is dissolved readily by sour milk products, such as whey and buttermilk, and instances of zinc poisoning of animals have occurred when they were fed sour milk from galvanized containers.

Chapter 3

THE VITAMINS IN MILK

Long before vitamins were known, careful observers had noted the association of certain foodstuffs with the prevention or cure of some diseases. In his book *Medicina Castrensis* written in 1720, an Austrian army surgeon named Kramer, announced that lemon or orange juice could be used as a cure for scurvy. This important discovery apparently was quickly forgotten. No other outstanding announcement relating to the vitamins was made for nearly 150 years. In 1880, a German investigator observed that there must be something in milk that was indispensable to nutrition since without milk mice could not be nourished successfully upon a diet of purified protein, fat, carbohydrate and salt.[46] In 1905, the Dutch investigator Pekelharing wrote that "there is in milk a still unknown substance which even in very small amounts is of paramount importance in nutrition." About the same time similar findings were made in England where it was announced that milk must contain *accessory food factors*, the very term we now often use for vitamins.[47]

In 1913 American investigators found that milk fat possesses a fat-soluble substance which is necessary for growth.[48, 49] Further research showed that there were present in other foodstuffs substances of unknown composition which had similar properties. The term *vitamine* was coined for these substances upon the assumption that they were necessary to life, *vita*, and to denote that they contained a nitrogenous substance, *amine.*[50] The latter assumption was shown to be wrong and the final *e* was omitted from the word in order to remove the association with nitrogen-containing amines. Later it was proposed that the vitamins should be designated by letters of the alphabet. This manner of identification generally was accepted but it has outgrown its usefulness since it is now possible to identify most of the known vitamins by their chemical composition.

A vitamin may be defined as a substance which exerts a definite

control over specific chemical reactions in the body; in fact the vitamins may be considered to act biologically as part of an enzyme system. The vitamins occur in extremely small amounts in vegetable and animal products and only minute amounts of them are needed to produce their specific effects in nutrition. They must be supplied in the diet. However, in some cases they may be formed in the body from other substances furnished by the diet. A lack or insufficient amount in the diet of some vitamins leads to disease. A vitamin deficiency disease is called an "avitaminosis."

Each vitamin, or perhaps a group of related vitamins, appears to be more or less specifically related to the proper functioning of some tissue or organ of the body. For example, vitamin A is needed by the epithelial tissue, that is, the skin and the mucous membranes. The vitamin B complex is important for the nervous system and for the proper utilization of carbohydrates, vitamin C for the intercellular substance of the blood vessels, vitamin D for the development of the bones and vitamin E appears to be needed for the reproductive system of some animals. Some animals can live normally without the presence of certain vitamins in their food. They either can form the vitamin from other materials in the diet or else they can thrive on such undetectable amounts of the vitamin as may be present in purified foodstuffs.

The popularity of vitamin-enriched foods and of self-medication with vitamin preparations, both largely encouraged by extensive advertising, has led to some investigation concerning the possibility of injury from an overdosage of vitamins. At present, it can be said that practically all competent investigators believe that several times the protective dose of a given vitamin is harmless. Extremely large doses, just like the intake of large amounts of sugar, salt or other foodstuff or condiment, may lead to untoward effects. The beneficial effects of the vitamins appear to have a ceiling or upper limit; it is of no use to increase the dosage beyond this limit.

Vitamin A

Vitamin A is a high-molecular weight alcohol of known chemical composition. It is widely distributed in foodstuffs of animal origin. In animal tissues the vitamin occurs chiefly in combination with the fats and when first studied was known as *fat-*

soluble A. The relationship between vitamin A and the yellow coloring material in plants was noted about 30 years ago, long before the chemical nature of the vitamin was established. It is now known that the vitamin A activity of plant materials is due to their content of carotene and related yellow pigments. The chemical name *carotene* is derived from the word carrot, a vegetable which is very rich in the pigment. There are at least four vegetable pigments: alpha-carotene, beta-carotene, gamma-carotene and cryptoxanthine, which can be converted into vitamin A by the animal body and therefore are called provitamins A. Cryptoxanthine is found in egg yolk and to some extent in milk-fat. Vitamin A itself is a pale yellow liquid at room temperature.[51] Animal products, such as fats, milk and butter may contain both carotene and vitamin A. Fish liver oils contain only the vitamin.

The symptoms of vitamin A deficiency have been described by many investigators. One of the first to appear is night blindness. As the name implies, this is an inability to see in dim light, such as one may encounter upon entering a motion picture theatre. Vitamin A is necessary for the normal functioning of a colored substance in the retina of the eye, known as *visual purple*. It is of interest to note that the Greek physician Hippocrates, who lived about 400 B.C., knew of night blindness and recommended the use of ox liver as a remedy. This, in fact, is a modern remedy since it has been shown that liver is a good source of vitamin A.

Another disease of the eye, known as xerophthalmia or extreme dryness of the mucous membrane of the eye, is caused by a lack of vitamin A. It is cured by the addition of the vitamin to the diet, provided that bacterial invasion of the eye tissue has not caused irreparable damage. This disease is rare in the United States, but at the time of World War I, it was prevalent in Denmark, especially among children. The consumption of butter had been decreased greatly having been exported to England and elsewhere, and as a result the population suffered from a lack of vitamin A in the diet. In order to prevent such an occurrence, many butter substitutes today are fortified with vitamin A obtained from fish liver oil. Carotene is not used for adding vitamin A to butter substitutes since the yellow color imparted would make the product liable to the tax levied upon colored butter substitutes.

The daily requirement for vitamin A needed in the diet is expressed usually in terms of International Units of the vitamin:

The International Unit for vitamin A is 0.0006 milligram of pure beta-carotene, an amount so small that it takes about fifty million units of vitamin A to weigh 1 ounce. The average daily requirement for children is estimated to be between 3000 and 6000 units; for adults, about 5000 units. Children under six years require less than 3000 units; nursing mothers need about 8000 units of vitamin A. This is about one or two parts of vitamin A in three million parts of food. It is a remarkable characteristic of modern food chemistry that such small amounts of a substance can be measured.

Vitamin A in Milk

Practically all of the vitamin A in milk is associated with the fat. There is no important difference in the vitamin A content of the milk of different breeds of cows when they are fed the same diet and the measurement is made on the basis of the fat content of the milk. Since Guernsey milk contains more fat, a quart of it will, as a rule, contain more of the vitamin than a quart of milk from Holstein cows, which milk has a lower fat content.[52] Milk produced during the summer months or pasture season is richer in the vitamin than milk produced at the end of the winter feeding season because the carotene which is present in green grass, is transferred to the milk and so increases its vitamin A potency, whereas the hay fed during the winter season is low in its carotene content.

There is no loss of vitamin A when milk is pasteurized, evaporated or dried.[53]

Butter made during the summer months has more vitamin A than butter produced during the winter season. Storage of butter for six months to one year does not diminish its vitamin A content.[54] For this reason butter made when the vitamin A content of the cream is high and stored for consumption during the winter months may be a richer source of the vitamin than fresh butter made in the winter season.

The average vitamin A content of various milk products is given in Table 5.

The Vitamin B Complex

The substance first identified as vitamin B is now known to consist of a number of substances, each of which is important to

health and nutrition. The separation and identification of these constituents has been accomplished during recent years and many of them now are manufactured commercially. The first vitamin of this group to be identified was vitamin B_1 or thiamine.

Thiamine

It became apparent to investigators about fifty or sixty years ago that certain diseases are of dietary origin. The Japanese navy found that beri-beri * among the sailors could be prevented if their diet contained meat and vegetables instead of the customary rice. Experiments made about 1897 in the Netherlands East Indies showed that a disease of chickens, very similar to beri-beri, could be cured, almost within an hour, if rice polishings were fed to the diseased fowl. This investigation was probably the first in which animals were used to study a disease of dietary origin.[55] Similar experiments made in this country led to the discovery of the vitamin which was called *water-soluble B*.[58] The vitamin, now known as *thiamine* (or aneurin in Great Britain), is of widespread occurrence in many foodstuffs, especially wheat germ, rice polishings, and yeast. Pure thiamine was first isolated from rice polishings and is now manufactured commercially by synthetic methods.[56]

In some countries, especially in the orient, a serious lack of the vitamin exists in the diet of people who live on polished rice and other restricted diets. In the United States symptoms of a gross deficiency of thiamine in the diet are rare, but there are indications that often a slight deficiency exists. Thiamine probably is less adequately supplied in the average American diet than any of the other known necessary food factors essential to health. The controlled enrichment of flour and cereal products to restore their original content of thiamine and certain other food essentials is now an accepted procedure to alleviate dietary inadequacies.

A deficiency of thiamine in the diet leads to such symptoms as moodiness, fear and mental as well as physical fatigue. A more serious deficiency causes loss of appetite, muscular weakness, vague pains or neuritis. As with many of the other vitamins, a

* Beri-beri is a Singhalese term meaning weakness or *I cannot,* which is characteristic of the symptoms of the disease.

lack of thiamine results in retardation of growth. It appears that with increasing food consumption the body's requirement for thiamine also increases.[57] The administration of large amounts of thiamine, such as twenty times the normal requirement, has no harmful effect. Continued feeding of very large amounts leads to an abnormal production of free fat in the liver cells and other disorders.

Thiamine is synthesized by plants, yeasts and bacteria but apparently not by higher animals. However, in the cow and other ruminents, a synthesis of the vitamins of the B complex occurs due to bacterial action in the first stomach or rumen. Thiamine must be supplied in the human diet, and since the body has little ability to store thiamine, the supply must be renewed constantly. Of the body tissues, only the liver, kidney, heart and brain contain appreciable amounts of the vitamin. As would be expected, only a small amount of thiamine is needed by the human body, the recommended intake being about 1 milligram for every 2000 calories in the diet. The daily requirements for thiamine and other vitamins is shown in Table 34.

Thiamine Content of Milk

Cows on a diet low in thiamine may secrete milk that contains a normal amount of the vitamin. This is due to the synthesis of the vitamin by the action of bacteria present in the rumen or first stomach of the cow. Even though the feed is rich in thiamine there is comparatively little transfer of it from the feed to the milk and it is impossible to exceed a maximum level of thiamine in the milk. This level is about 0.4 milligram (400 micrograms or 133 International Units) per quart of milk. Unlike the vitamin A content, the amount of thiamine in milk is very constant and does not vary with the season of the year. Milk is a fair but not a rich source of thiamine. Pasteurization destroys about 10 to 20% of the thiamine originally present in the milk and the loss is somewhat greater in the manufacture of evaporated and dried milk.[58, 59] A loss of only about three percent is reported to occur when milk is pasteurized by the short time-high temperature process.[60]

Riboflavin

Riboflavin is the name given to the vitamin known also as B_2 or G. A lack of riboflavin in human beings brings about an

inflamed and scaly condition of the skin around the corners of the mouth, the base of the nose and the ears. A disturbance of vision also may occur. It is unusual to find a person showing only a deficiency in riboflavin since a diet low in it usually is also low in the other vitamins of the B complex. Riboflavin is necessary for the oxidation processes which take place in all living cells.

Riboflavin is bright orange in color. Its aqueous solution is yellow-green with a strong fluorescence. It is widely distributed and usually is found with other factors of the B complex, in various green-leafed vegetables, heart, kidney, liver, lean meat and milk. It is prepared commercially in pure form by a synthetic process.

Riboflavin is found abundantly in milk and first was isolated from whey, the yellowish color of which is due to the presence of riboflavin. Before its vitamin nature was known, the yellow pigment was known as lactoflavin or lactochrome. The amount in milk is fairly constant but appears to be more dependent upon the feed of the cow than is thiamine; the largest amount is present when the cow is on green pasture. Since riboflavin is water-soluble, it is not found in the fat of milk. When skim milk or whey is dried, the powder is an especially rich source of riboflavin. There is no appreciable destruction of riboflavin when milk is pasteurized or evaporated. If the milk is exposed to light, especially direct sunlight, a loss of riboflavin takes place, which may reach eighty percent after an exposure of four hours.[61, 62] The daily requirement of the vitamin and the amount found in various milk products is shown in Tables 5 and 34.

Niacin

Niacin or nicotinic acid is the name of another vitamin of the B complex. Niacin is a white, crystalline compound. It can be made synthetically and is available commercially.

Niacin or the compound called niacinamide is a dietary essential. It probably is the same as the vitamin called the pellagra-preventing or P-P factor. Diets in areas where the nutritional disease called pellagra is prevalent are deficient in niacin, although other dietary deficiencies probably are involved in the disease, which is widespread in the southern United States, Italy and southeastern Europe.

In the southern United States many people of low-income live on a diet of salt-pork, corn meal and molasses, none of which are adequate in niacin content. Beef, chicken, heart, kidney, liver and peanut butter are among the more common foods relatively rich in niacin. Milk is a poor source of this vitamin. The daily requirement of niacin and the amount found in some milk products are shown in Tables 5 and 34.

There is no evidence that exposure to light, pasteurization, evaporation or drying causes any loss of niacin in milk.[63]

Pantothenic Acid

Of the factors present in the vitamin B complex, pantothenic acid has received considerable popular attention. It was found that gray hair develops on the body of rats whose diet is deficient in this vitamin. As a result pantothenic acid received publicity as the anti-gray hair vitamin. In spite of considerable investigation, there is as yet no scientific basis for such a belief, at least, so far as human beings are concerned.[64]

Pantothenic acid appears to be essential for the nutrition of animals, certain plants and probably for human beings. Traces of it are present in many foodstuffs. Its name comes from the Greek word meaning *from everywhere,* in reference to its presence in so many substances. It is needed for growth and the prevention of a form of pellagra that occurs in chicks. The vitamin, usually in the form of its calcium salt, is made synthetically and is available commercially. Table 5 shows the amount of pantothenic acid contained in various milk products. There is no loss of pantothenic acid when milk is exposed to sunlight, or pasteurized, evaporated or dried.[63]

Other Factors in Vitamin B Complex

A number of compounds other than those mentioned in the previous paragraphs are present in the B complex. All seem to be needed for growth and health. Among those that have been identified are vitamin B_6 or pyridoxine,[65] folic acid,[66] biotin,[67] choline,[68] inositol [69] and para-amino-benzoic acid. All have been found to be present in milk.[67] Choline is a nitrogenous compound which also is part of the lecithin molecule. .In the normal diet

the proteins are the principal source of choline. It has been shown that pyridoxine is needed for the metabolism of certain amino acids.[65] Both choline and pyrodoxine seem to be necessary for the proper utilization of fats by the body.[67] The same holds true for inositol.

Ascorbic Acid (Vitamin C)

The fact that scurvy could be cured or prevented by fresh fruits in the diet was recognized over 200 years ago, but it has been only during the last 40 years that systematic investigation showed that human scurvy was a vitamin-deficiency disease. Vitamin C was isolated and identified in 1933. It now is manufactured synthetically.[70]

Ascorbic acid is essential to the proper functioning of the glandular system of the body. It appears also to play an important part in the bodily defense against infections. A deficiency of the vitamin in the diet lowers the resistance to infections and leads to defective teeth. If the lack is serious scurvy may occur and the symptoms associated with this disease, such as swollen gums, loose teeth, gastric ulcer, hemorrhage and anemia. Scurvy is very rarely seen in infants under 6 months of age, perhaps because they are breast-fed. The mother's milk may contain up to six times as much ascorbic acid as cow's milk. A very early symptom of scurvy in an infant is pain or tenderness of the legs when the child is handled.[71]

Ascorbic Acid in Milk

The ascorbic acid content of cow's milk appears to be fairly uniform and independent of the season of the year and the animal's diet.[72, 73] The average amount in fresh, raw milk is about 20 milligrams per quart, which is much less than the recommended dietary requirement. During ordinary processing operations, milk loses an appreciable part of its ascorbic acid. Much of the ascorbic acid is destroyed when milk is dried or heated in the presence of air. This loss of the vitamin is hastened if a minute amount of copper is present. Milk pasteurized by the ordinary vat-holding method in which it is exposed to the air, loses about one-half of its ascorbic acid content, when pasteurized out of contact with

the air, or by the short time, high temperature method, the loss of the vitamin is not material. Some destruction of ascorbic acid occurs when milk is irradiated to increase its vitamin D potency. Considerable loss occurs when milk is evaporated or dried.[74, 75] The fortification of evaporated milk with ascorbic acid is discussed in Chapter 12.

The daily requirement of ascorbic acid and the amount found in various milk products is given in Tables 5 and 34.

Vitamin D

The American investigator, A. F. Hess suggested that vitamin D should be called the *calcifying vitamin* rather than the "antirachitic vitamin" since it is essential to the proper assimilation of calcium and phosphorus for the normal calcification of bones in young animals and children. Rickets, which may start in the second or third month of an infant's life, is characterized by an enlarged abdomen, softness of the bones and delayed dentition. This disease is associated with a lack or improper balance of calcium, phosphorus and vitamin D in the diet. As will be shown later, exposure to direct sunlight is a substitute for vitamin D to some extent.

Since calcification of the permanent teeth begins after the age when rickets usually occurs, dental caries or tooth decay, is not due to rickets; it is probably related to malnutrition and a deficiency of vitamin C as well as vitamin D. A lack of vitamin D in adults may cause a softening of the bones, especially in the case of nursing mothers.

At least fourteen substances have been stated to have vitamin D activity, but of these, only two are of importance in human nutrition. Vitamin D_2 or calciferol is formed when ergosterol, a wax-like alcohol obtained from yeast, is irradiated with ultra-violet light. This is the form of vitamin D in irradiated yeast, *metabolized* vitamin D milk and in the medicine, Viosterol. Vitamin D_3 is the form found in natural sources of vitamin D. It is formed by the irradiation with ultra-violet light of the compound known as 7-dehydrocholesterol. It is found in some fish-liver oils, animal fats, egg yolk and in irradiated milk. Exposure of the skin to sunlight or ultra-violet light results in the formation of vitamin D_3 which is utilized by the body just as if it were supplied by the diet.

The usual method employed to measure the vitamin D activity of a foodstuff is to feed definite amounts of it to test animals, usually rats or chicks, raised on a vitamin D free diet and to note the rate of bone formation. Many vitamin D assays are made by means of the *line test,* in which the animal is killed and the amount of new bone formation in the leg bone is observed. The first indication of new bone formation is a more or less continuous line of band-like deposition of calcium phosphate in the bone, hence the name *line-test.*

A

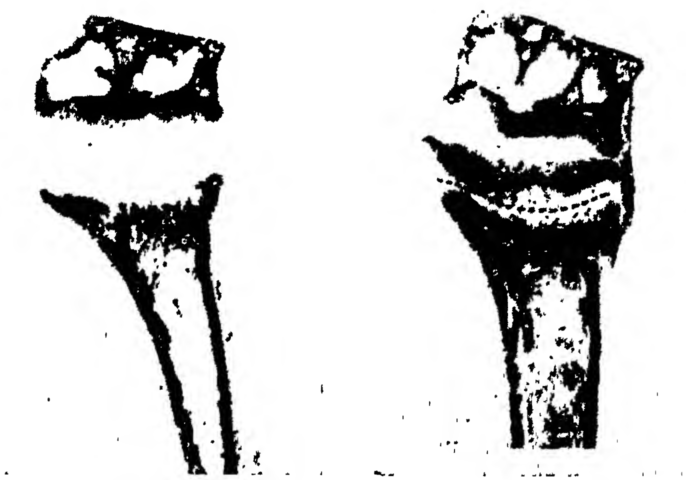


FIG. 6. Line Test for Vitamin D

Left: Leg bone (radius) of rat fed a diet deficient in vitamin D. The white band (A) shows growing portion of bone, devoid of calcium, between the tip of the bone and the older calcified bone below.

Right: Leg bone of rat (radius) showing calcification after diet contained vitamin D. Note that calcium (dark band above dotted line) is being deposited in the area formerly devoid of the mineral.

The International unit of vitamin D is the activity of one milligram of a solution of irradiated ergosterol dissolved in olive oil which is equivalent to the potency of 0.025 micrograms of crystalline calciferol.

Vitamin D in Normal Milk

Milk, butter, eggs and liver are the only foods which contain appreciable amounts of natural vitamin D. Most of the vitamin

is found in the fat. Compared to certain fish-liver oils, milk fat is a poor source of the vitamin. The content of vitamin D in milk is highest during the summer months and lowest in February, which, of course, is due to variation in the cow's diet and exposure to sunlight. There is no evidence to show that pasteurization destroys any of the vitamin D activity of milk. The daily requirement of vitamin D and the amount found in different milk products is given in Tables 5 and 34.

Vitamin D in Milk

Since the diet of most children is deficient in vitamin D, it has become a commercial procedure to add the vitamin to milk, especially to canned evaporated milk. A number of methods may be used to increase the vitamin D content of milk. Natural milk may contain from 4 to 60 International units of vitamin D per quart.[76] If the cow is exposed to sunlight or ultra-violet light or if her udder is exposed to ultra-violet light irradiation, the vitamin D potency of the milk is increased to some extent, but the results of this procedure are too variable to be considered satisfactory or of commercial importance.

Metabolized Vitamin D Milk

Vitamin D is one of the few substances important to nutrition which when fed to the cow appears in the milk. Materials rich in vitamin D, such as fish liver oils, irradiated yeast or irradiated ergosterol, may be added to the cow's feed in order to increase the vitamin D content of her milk. The use of fish liver oil is not recommended since it may impart an undesirable flavor to the milk or decrease the amount of milk given by the cow.

The cow is very inefficient in the transfer of the vitamin to the milk. Measurements show that less than 2% of the amount fed appears in the milk.[77] This small amount nevertheless is enough to increase the vitamin D potency of the milk about fifteen times, so that the milk will contain about 430 international units per quart. This potency coincides with the minimum daily requirement recommended for children by the Council on Foods and Nutrition of the American Medical Association (see Table 34).

Fortified Vitamin D Milk

Concentrates made from certain fish-liver oils or from irradiated ergosterol mixed with vegetable oil, milk or cream, may be added directly to milk in order to increase its vitamin D content and yet not affect the flavor of the milk. Usually sufficient concentrate is added to bring the potency up to at least 400 units of vitamin D per quart of milk. Most evaporated milk is so fortified that when it is diluted with an equal volume of water, the resulting solution contains 400 units of vitamin D per quart. The direct addition of a vitamin concentrate to milk has the advantage that the potency can be controlled by adding known amounts of the vitamin, but care must be exercised that the proper amount of concentrate should be added.

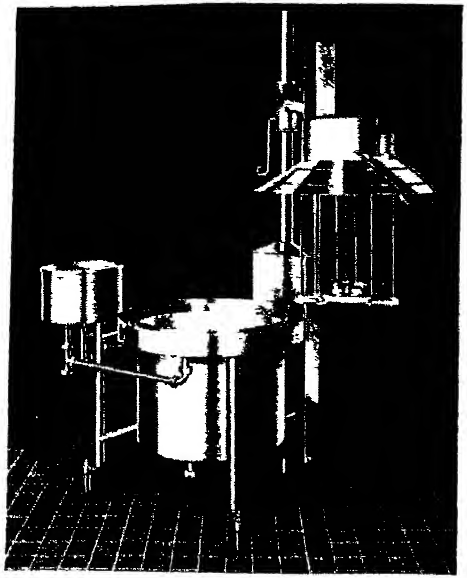
Irradiated Milk

Direct irradiation with ultra-violet light often is used to impart vitamin D activity to foodstuffs, including milk.[78] Ultra-violet light cannot penetrate to any depth in a milk film and about 75% of the effective irradiation is absorbed in the first 0.02 millimeter (about 0.0008 inch) of the milk film. Since a long exposure to ultra-violet light imparts an unpleasant flavor to milk, the time of exposure is short, usually about 3 seconds and the milk flows in a very thin film during the irradiation. Mechanical control of the irradiation makes it possible to produce a milk product with a definite vitamin D potency, usually not exceeding 200 units per quart. Up to about 1945, much evaporated milk was irradiated but this procedure was not found sufficiently practical to add 400 units, as now recommended. Evaporated milk now is fortified with vitamin D concentrate.

Irradiation sufficient to produce 200 units of vitamin D does not effect the carotene, vitamin A, thiamine or riboflavin content of the milk. Illustrations of equipment used to irradiate milk are shown in Figure 7.

Multi-Vitamin Milk

Some distributors of dairy products offer vitaminized milk which contains therapeutic doses of vitamin A, thiamine, ribo-



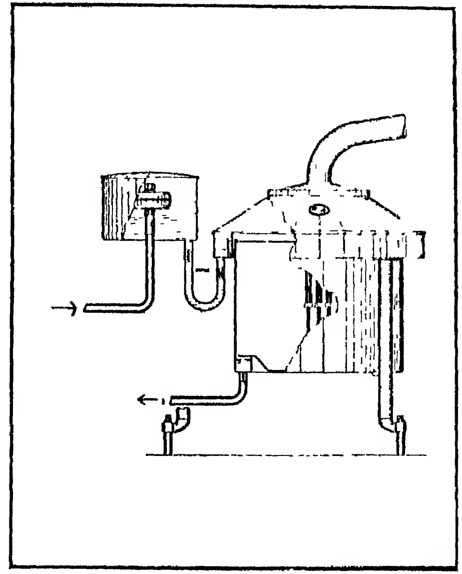


Fig. 7 *Carbon Arc Milk Irradiator*

Left: Irradiator in open position for cleaning.

Right: Irradiator in operation, sectional view. Milk flows by gravity from the constant head tank (left) to the distributing trough around the upper edge of the irradiator. The evenly distributed overflow around the entire inner surface of the cylinder is exposed to ultra-violet light from the three carbon arcs in the center of the irradiator. *(Courtesy of National Carbon Co.)*

TABLE 5

Vitamin Content of Milk and Milk Products
(Per 100-Gram Portions)

(Based upon data in Circular 638, U. S. Department of Agriculture, 1942)

Product	Vitamin A International Units	Thiamin Micro-grams	Riboflavin Micro-grams	Ascorbic Acid Milligrams	Vitamin D International Units	Other Vitamins Micrograms
Butter [1]	800–1400	3	8	.....	8–30	
Butter [2]	2000–3200			......	20–120	
CHEESE						
Cheddar	1200–2000	10–42	340–520 [e]	......	3	
Cottage	200–700	......	300	.....	......	
Cream	2200	......	150	......	162	Micrograms per 100 grams.
Limburger	1280–1460	......	360	......	......	Pantothenic acid, 1550
Roquefort	4010	30	410	......	.....	Niacin, 2000
Swiss	2200	......	......	......	......	Biotin, 12.2 (Dry Basis)
Ice Cream (Vanilla)	330	35	110	...	.....	
MILK [1]	130–200	20–50	175–275	1.4–2.6 Average 1.9	0.5–4.6 Average 2.0	Biotin, 6–8 [a] Inositol, 14,000
MILK [2]	200–260	.....	.....	0 07–1.47 Average 1.0	......	Folic acid, 15 Pantothenic acid, 350 Pyridoxine, 67 [g] Niacin, 80 [b] Choline, 14 [g]

TABLE 5 *(Continued)*

Product	Vitamin A International Units	Thiamin Micro-grams	Riboflavin Micro-grams	Ascorbic Acid Milligrams	Vitamin D International Units	Other Vitamins Micrograms
MILK, Vitamin D						
Metabolized	As above	As above	As above	As above	43	
Fortified	As above	As above	As above	As above	41	
Irradiated	As above	As above	As above	As above	13.5	
Milk, Skim	17	......	......	......	......	Pantothenic acid,[e] 210-430
Milk, Dry Whole....	1400	315	1000–2500	6 9–9.7	......	Niacin, 500–900 Calcium Pantothenate, 2900 Biotin, 41 Pyridoxine,[k] 240–460
Milk, Dry Skim.....	140	255–375	1700	6–8	......	Pantothenic Acid, 4600
Milk, Evaporated[d] ..	464	30–58	357[h]	0.4–2.76 Average 1.3	2.9	
Milk, Evaporated and Fortified	.....	.....	..... .	.. ...	84 5	
Milk, Sweetened Condensed[d]	280	96–180	396[h]	......	.... .	
Milk, Human[d]	100	9.3–20.1 Average 15[f]	25–35	2–10 Average 5	0.5–4.0	Inositol, 33[i] Folic Acid, 45 Niacin, 180 Pantothenic Acid, 246 Pyridoxin, 4 Biotin, 0.8
Buttermilk	......	......	155[d]	......	......	Pantothenic acid, 350–560

Whey	......	......	124 [h]	......	......	Pantothenic acid, 240–570
Whey, Dry	......	.....	2800	......	......	

[1] Produced during fall and winter months.

[2] Produced during spring and summer months.

[a] R. R. Williams, *J. Am. Med. Assoc.*, 119 (1942).

[b] Brown, Thomas and Bina, *Cereal Chem.*, 19, 447 (1942).

[c] T. H. Jukes, *J. Nutrition*, 21, 193 (1941).

[d] Per 100 milliliters (3.38 fluid ounces).

[e] Studies on the Riboflavin Content of Cheese, *Neb. Agri. Exp Stat. Res. Bull.*, 137 (1945).

[f] Knott et al., *J. Pediat.*, 22, 43 (1943).

[g] A. Z. Hodson, *J. Nutrition*, 27, 415 (1944).

[h] L. Daniel and L. C. Norris, *Food Research*, 9, 312 (1944).

[i] J. M. Lawrence, B. H. Harrington and L. A. Maynard, *Am. J. Diseases Children*, 70, 193 (1945).

[k] P. F. Sharp, K. B. Shield and A. P. Stewart, *Proc. Inst Food Tech.*, 54 (1945).

flavin, niacin, pantothenic acid and other vitamins, as well as additional amounts of iron and iodine. There may be a certain demand for these products, but the Council of Foods and Nutrition of the American Medical Association has taken a stand against such additions, except for vitamin D. It is maintained that there is little need to fortify milk with vitamin A and that fortified cereal foods, flour and baker's bread are more important vehicles than milk for supplying thiamine, riboflavin and niacin.[79, 80]

The addition of vitamins D and C to evaporated milk is discussed in Chapter 12.

Chapter 4

SOME FUNDAMENTALS OF DAIRY BACTERIOLOGY

The importance of obtaining a milk of good sanitary quality and low bacterial content cannot be overemphasized. Although the composition and therefore the food value of milk as it comes from the cow is an established fact, the cleanliness and safety of the product are under human control. Thus, if milk is to be of good quality it must come from healthy cows, kept in clean surroundings. To be of low bacterial content, the milk must be obtained with clean equipment and stored at a low temperature until processed or consumed.

A commonly used procedure to judge the sanitary quality of milk is to determine its bacterial content. Bacteria are tiny organisms, among the simplest forms of life. They are invisible to the unaided eye and some are so small that they hardly can be seen even under the microscope. Even the largest of them are so small that about five hundred of them would have to be placed end to end to make a line one inch long. Most bacteria are less than one-tenth of this size. Some conception of their size may be gained when it is realized that a single drop of sour cream may contain more than fifty million bacteria.

Although invisible to the naked eye, the bacteria which may be present in a milk product become evident through their activities. Because of their presence milk may become sour, or develop a bad odor and flavor. Many people envisage something unpleasant or dangerous when the word bacteria is mentioned but fortunately very few of the large number of bacteria known are harmful to man. Most foods contain bacteria and practically everything with which one comes in contact is covered with or contains them. They are present in and on our bodies, and while they may be removed temporarily from the skin by means of special chemicals, it is impossible to remove them from our bodies.

The normal life cycle of a bacterium (singular of bacteria), like that of all other living beings, includes growth, reproduction

and death. Bacteria reproduce by cell division; that is, the organism actually divides into two parts, each of which then becomes a separate, living bacterium. In many cases a new generation may be formed in this manner every 20 minutes. Thus, at the end of this time, one bacterium has become two; in about 40 minutes, these have become four and at the end of an hour the original organism has given rise to eight bacteria. Since bacteria usually are present in fairly large numbers, reproduction at this rate can produce a very large population within a short time. Reproduction however cannot continue indefinitely since some of the bacteria die, the available food supply decreases and the accumulation of by-products of bacterial growth finally discourages further growth.

When conditions for growth are not favorable, certain bacteria have the remarkable ability to transform themselves into small bodies called spores. The word *spore* comes from the Greek word for *seed*. However, the bacteriological spore is not a form in the reproduction cycle; it is only a means by which the organism protects itself against conditions which otherwise would be fatal. The spore, for example, can often withstand drying, the temperature of boiling water and the action of some germicides, which would destroy the organism in its original growing or vegetative state. When suitable conditions return, the spore resumes its vegetative form and the bacterium again returns to the usual activities of its normal life cycle.

Classification of Bacteria

So many different kinds of bacteria are known that it is necessary to have some method of classification in order that they can be identified. Usually bacteria are placed into groups according to their shape as seen under the microscope. Organisms which are longer than they are wide, rod-shaped in other words, are called *bacilli* (singular, *bacillus*). Bacteria that are round or ball-shaped are known as *cocci* (singular, *coccus*). Unlike many of the rod-shaped organisms, the cocci do not form spores. The manner in which the cocci divide at reproduction furnishes a further means of classification. If the cells remain connected end-to-end after division, a bead-like chain is formed. Such organisms are known as *streptococci*. Cocci that form grape-like clusters are called

staphylococci. Others that divide in such a manner that they form a flat or sheet-like mass of cells are known as *micrococci.*

The bacilli and the cocci are the most common forms of bacteria found in milk. The streptococci often are present in milk which was not cooled properly after milking. The micrococci frequently are found on dairy equipment which was not cleaned properly or had not been sterilized or dried after cleaning.

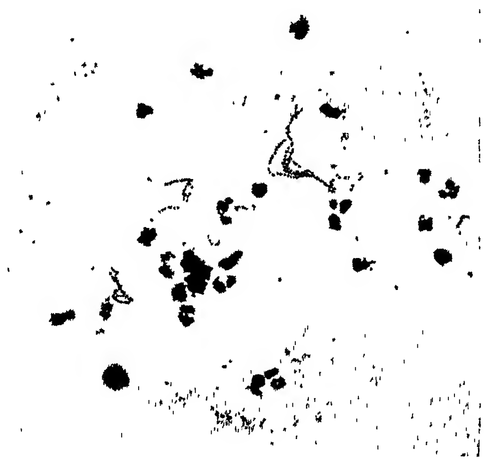


FIG. 8. *Microscopic appearance of milk from a cow suffering from mastitis* Numerous leucocytes are present as well as long-chain streptococci. X 600. *(New York Agr. Expt. Sta. (Geneva) Circ. 93.)*

Some organisms can live only in the presence of air; they are called *aerobes.* Other bacteria, called *anaerobes,* can live without air and get the oxygen they need from the food they consume. Another group, known as *facultative* organisms, have the ability to adapt themselves to changes in environment so that they can live in contact with the air or without it.

When living in liquid surroundings, many bacteria are able to propel themselves through it by means of hair-like arms called *flagella.* This word comes from the Latin word for whip and the bacterium actually moves itself by thrashing the liquid with its flagella. Some bacteria have their bodies covered with a gelatinous coating or envelope called the *capsule.* Capsulated organisms are associated with certain defects in milk, as will be mentioned later.

Cultures

In order to study bacteria, they must be grown in surroundings suitable for their growth. Bacteriologists grow the organisms on a food of standardized composition, known as a *medium* (plural, media). A growth of bacteria of one type in a medium favorable to their life habits is known as a *culture*. In dairy bacteriology, sterilized skim milk is a common medium for bacteria used to start the fermentation of milk in the manufacture of cheese or to sour milk or cream. Such a culture is called a *starter*. The interval during which the fermentation proceeds and the acidity increases or flavor and aroma develop is known as the *ripening* period.

The maximum number of organisms growing in a culture is controlled by a number of factors, such as the kind of bacteria present, the composition of the medium, its temperature and degree of acidity. For example, in the manufacture of cheese, a culture or starter of bacteria that form lactic acid is added to a vat of warm milk. These organisms find the warm milk favorable to their growth and reproduction is so rapid that they outgrow any other bacteria that originally might have been present in the milk. If allowed to develop, these other organisms might form gas or bitter substances which would make the cheese less palatable. The organism used in dairy cultures for the manufacture of cheese and other milk products in which acid formation is desired is known as *Streptococcus lactis*. Other organisms used for special types of fermentation will be mentioned later.

The bacteriologist has a system of naming the bacteria. The first part of the name gives the genus or family to which the organism belongs; the second part indicates the species or variety within the genus. The genus name is always spelled with a capital letter. Often only the first letter or letters of the genus name are used. The species is always spelled with a small letter. Thus, *Streptococcus lactis* or *S. lactis* means that the organism belongs to the streptococci or chain-formers and to the lactis variety.

Temperature and Bacterial Growth

Temperature is an important factor in controlling the rate of growth of bacteria. Most of them prefer a temperature between

68° and 98°F., the range between that of a fairly warm room and that of the human body. These organisms sometimes are called *mesophilic* bacteria, which means that they prefer the middle or moderate range of temperature. Some organisms prefer a temperature lower than 68°F. and are called *psychrophilic* bacteria, meaning those that *like a low temperature.* Of greater importance to the dairyman are the *thermoduric* and *thermophilic* bacteria. Thermoduric means *able to withstand heat*; thermophilic means *to enjoy heat.* Thermoduric bacteria are not destroyed at the temperature used to pasteurize milk but they do not reproduce at this temperature. Thermophilic organisms, on the other hand, not only like warm surroundings but are able to reproduce at the temperature used for the holding method for pasteurization of milk, about 143°F.

Since the purpose of pasteurization is to destroy bacteria that may be present in milk, the presence of either thermoduric or thermophilic organisms is undesirable. Fortunately, these organisms are of no practical importance from a public health point of view since they are harmless and, unless millions of them are present, have no effect upon the flavor or appearance of milk. A large proportion of any thermophilic bacteria that may be present in milk dies when the milk is held for some time at a low temperature, which generally is the case before milk is delivered to the consumer.[81]

Low temperatures slow down the growth of bacteria and lower the rate of reproduction. The number of organisms in a product generally decreases gradually when it is held under refrigeration. However, even extreme cold does not kill certain bacteria, and spores may withstand the temperature of liquid air, about 310° below 0°F. A high temperature, especially in the presence of moisture, is destructive to bacterial life. The exact temperature at which an organism is destroyed is rather indefinite, because it is influenced by the age of the cell, the medium in which it is present and the length of time for which it is exposed to heat. Young cells, for example, are killed more readily than older ones; dry heat is not as destructive as live steam. The presence of sugar seems to give some protection to certain bacteria. The term *majority thermal death point* is used to indicate the temperature at which most of the cells of a given organism are destroyed within a given time.

The effect of temperature upon the rate of growth of bacteria in milk was demonstrated in an investigation made in 1930 at the University of Vermont.[52] It was found that at 80°F. the number of organisms in a sample of milk doubles in about 1½ hours; at 60°F. more than 4 hours are needed to double the number originally present; at 50°F. about 8 hours, and if the milk is held at 40°F. about 39 hours. When held at room temperature, milk sours much more quickly than when held in a refrigerator, since the bacteria that cause the development of acid grow much faster at about 70°F. than at a lower temperature. This also explains the popular superstition that milk will sour or curdle during a thunderstorm. The actual reason for this is that the warm weather preceding the storm favors the growth of bacteria. If the milk is kept cold nothing unusual happens.

The Significance of Bacteria in Milk

If milk is to be of good quality and safe to use, it must be obtained from healthy cows milked in clean surroundings. The

FIG. 9. *Microscopic appearance of milk that had been handled in poorly cleaned utensils*

The organisms present cannot be identified by microscopic examination alone. Masses of micrococci often are present, sometimes non-spore forming rods and occasional large spore-forming rods. X 600. *(New York Agr. Expt. Sta. (Geneva) Circ. 93.)*

Fig. 10. *Microscopic appearance of improperly cooled milk, souring normally*
The predominant organism is Streptococcus lactis, which often is present in pairs (diplococci) and in threes and double pairs. The insert shows two pairs enlarged 2000 times. The lower pair shows a faint indication of division into four cells. *(New York Agr. Expt. Sta. (Geneva) Circ. 93.)*

Fig. 11. *Microscopic appearance of high grade milk*
In this picture no bacteria are seen. The spaces left after the fat globules are dissolved from the smear appear as white areas. Leucocytes or epithelial cells may be present in high grade milk, but few bacteria may be found on microscopic examination. *(New York Agr. Expt. Sta. (Geneva) Circ. 93.)*

equipment used to handle and process the milk must be of approved design and kept in a clean and sanitary condition. When care is taken in its production, milk contains relatively few bacteria and, generally, it may be regarded as a better and safer product than milk with a high bacterial content. The presence of many bacteria or as it is commonly expressed, a *high count,* does not necessarily indicate that the product is unsafe to use since the organisms usually found in milk do not cause disease.

A high count indicates that the milk was handled in dirty equipment or produced under undesirable conditions, that the cows were diseased or that the milk was held in a warm place. Although a low count indicates that the milk probably was produced under good conditions, this does not give the assurance that the milk was not obtained from a tuberculous cow or was not otherwise subjected to contamination. Harmful organisms are rarely found in the cow's udder, except if the cow suffers from tuberculosis or brucellosis. Contamination of the milk from external sources presents a different problem. Milk may be contaminated by a diseased milker or by contact with infected water or dirty equipment. Pasteurization eliminates the possibility of the transfer of harmful organisms through milk.

Counting the Bacteria in Milk

A commonly used procedure to measure the sanitary quality of milk is to determine its bacterial content. There is no known method by which the absolutely exact count of the number of bacteria present can be obtained. Furthermore, none of the methods in common use is capable of making known the presence or absence of disease-producing organisms. The bacterial count usually is expressed as the number of bacteria found per milliliter (ml.), approximately 1/29th ounce. Often the term *cubic centimeter* (cc.) is used instead of milliliter. The volumes* are practically the same but *milliliter* is the correct term. In the case of non-liquid products the count is expressed on a weight basis, that is, the number of organisms per gram of product.

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* One ml. equals 1.000028 cc. (U. S. Bureau of Standards Circular C434).

The Plate Count

The agar plate count [53] generally is used for the routine examination of milk by health departments and control laboratories. It is capable of giving results on milk that may contain either very few bacteria or millions per milliliter.

In the method a small, known volume of milk is mixed in a Petri dish (plate generally used) with a jelly-like medium that contains agar and nutrient materials that favor the growth of bacteria. Various media, including the standard nutrient agar (tryptone-glucose-extract-milk agar)* are available commercially in dehydrated form. The prepared medium melts when warmed and in this condition may be mixed easily with the milk sample. The mixture soon solidifies again at room temperature. The covered Petri dish prevents the entry of bacteria other than those present in the milk sample. These are nourished, grow and reproduce quickly. One bacterium is invisible to the naked eye, but in the medium the rate of growth and reproduction upon incubation is so great that vast numbers soon are present. Thus a group of bacteria growing in a fixed position on the medium forms a mass visible to the eye. Such a mass is called a *colony*. Each colony corresponds to one living bacterium or a group of bacteria originally present in the milk added to the medium. By counting the number of colonies formed, a measure is obtained of the number of bacteria present in the sample. In order to facilitate the counting, a magnifying lens usually is used in the examination of the Petri dishes.

The general procedure for making the plate count is described below but the *Standard Methods for the Examination of Dairy Products*, 9th Ed., 1948, should be consulted for details. These details should be adhered to closely since slight deviations may result in unreliable counts.

Thorough agitation of the milk is necessary before it is

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* Standard tryptone-glucose-extract-milk agar is prepared as follows: In 1 liter of water, dissolve 5 grams tryptone, 3 grams beef extract, and 1 gram glucose. Add 15 grams agar and heat over a flame, stirring to prevent burning on the bottom, or place in an autoclave until the agar is dissolved. Replace any water lost by evaporation. Add 10 grams of skim milk just before final sterilization in all cases when the medium is used for dilutions greater than 1:10.

sampled. If the milk is in a large container, mix with a sterile stirrer long enough to reach to the bottom of the vessel, or if practical, mix by repeated forceful inversions of the container. Samples may be taken from well stirred cans or vats with a sterile metal tube. If the sample is not to be plated immediately, place it in crushed ice or otherwise hold at a temperature between 32° and 40°F. All equipment used for the plate count, such as

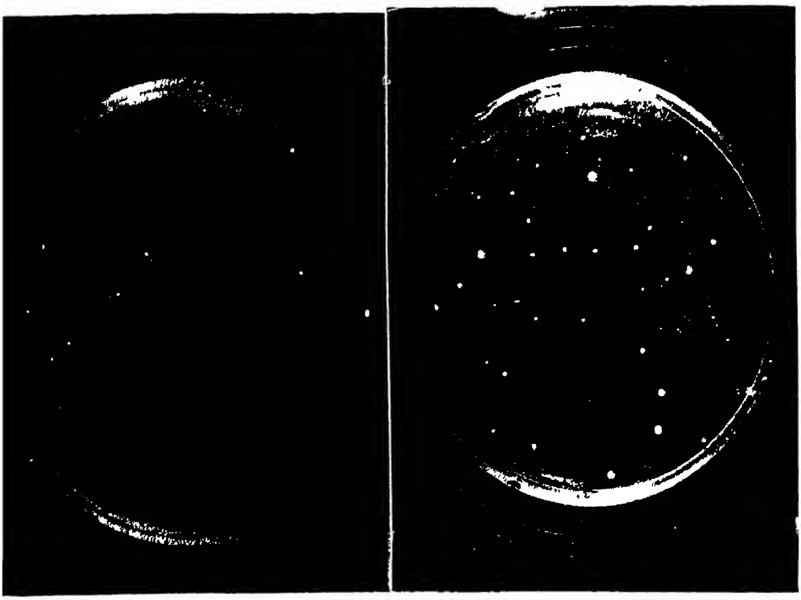


FIG. 12. *Colonies of Bacteria Growing on Agar Medium in Petri Dishes*
Left: Plate inoculated with 1 to 100 dilution of good quality milk. Eight visible colonies represent a count of 800 bacteria per ml. of milk.
Right: Plate inoculated with 1 to 100 dilution of pasteurized cream. 210 colonies represent a count of 21,000 bacteria per ml. of cream.

pipettes, dilution bottles, and Petri plates must be sterile to prevent contamination of the milk under examination.

The bacteria in milk and cream usually occur in groups of 2 to 6 individuals. Immediately before plating, shake the sample 25 times within 7 seconds, each shake being an up and down excursion of about 1 foot, in order to break apart the clumps of organisms.

Use at least two different dilutions of the sample, preferably 1:100 and 1:1000. One milliliter of sample added to 99 milli-

liters of sterile water gives a 1:100 dilution. After thorough shaking, add 1 milliliter of the 1:100 dilution to another container with 9 milliliters of sterile water in order to make a 1:1000 dilution. If desired, 0.1 milliliter of the sample may be added to 99.9 milliliters of sterile water for the 1:1000 dilution. If a low bacterial content is expected, prepare plates from 1:10 and 1:100 dilutions. Prepare dilutions of the sample so that the number of colonies on at least one plate will be between 30 and 300.

Shake the dilutions in the same manner as used for preparing the sample. Then transfer 1 milliliter to an empty, sterile Petri dish, using a separate, sterile pipette for each sample and for each dilution. When measuring, hold the pipette at an angle of 45° against the Petri plate or neck of the dilution bottle. Allow the pipette to drain and then touch once against a dry spot on the glass. Raise the Petri dish cover only high enough to insert the pipette.

With a wax pencil mark the cover of the Petri dish with the sample number and dilution used. A convenient way to mark the dish is to place the sample number near the bottom of the cover to indicate a 1:10 dilution, in the middle of the cover for a 1:100 dilution and near the top for a 1:1000 dilution.[84]

Pour from 10 to 12 milliliters of melted agar medium at 41° to 44°C. into each plate. An excess of agar favors a spreading growth of surface colonies. The interval between the first transfer of the sample and the addition of the agar must not exceed 20 minutes. Lift the cover of the dish only high enough to pour the agar. Mix the sample and agar thoroughly by rotating and tilting the dish carefully. Do not allow the mixture to splash over the edge of the plate.

As soon as the agar has solidified, invert the plates and place them in the incubator. Incubate for 48 hours at a temperature of either 37°C. (98.6°F.) or 32°C. (89.6°F.). The lower temperature is more favorable for the growth of the bacteria commonly found in milk.* After incubation, count the colonies on the plates, preferably with a Quebec type colony counter and multiply by the dilution used. This will give the

* The 9th Edition (1948) of *Standard Methods of Milk Analysis* will specify that plates should be incubated at either 32° or 35°C.

plate count per milliliter of sample. If the number of colonies on the plate exceeds 300, a fraction of the plate may be counted. Plates with fewer than 30 colonies should not be counted, unless they are the only ones available. In cases of doubt, a microscope should be used to distinguish between colonies and foreign material.

FIG. 13. *Colony Counter (Quebec Dark Field)*

The Petri dish is placed on the illuminated guide glass. The markings on the guide enable the operator to estimate the number of bacteria present on crowded plates by counting a few areas and then multiplying by a factor. In this picture the operator is removing a colony with a sterilized platinum wire loop for further examination. *(Courtesy of American Optical Co.)*

Counts from agar plates give the *estimated* number of colonies that would have developed if an entire milliliter of milk had been examined under the specified conditions. Since an unknown ratio exists between the colony count and the total number of bacteria, it is incorrect to speak of the plate count

as showing the number of bacteria per milliliter. The results should be reported as *Standard Plate Count per milliliter.* Only the two significant left-handed digits are used in reporting the count, the third figure being raised to the next highest number but never lowered. Thus a colony count of 225 in a 1:100 dilution plate is reported as a *Standard Plate Count of 23,000 per milliliter* not 22,500.

A series of at least four or more samples should be examined before the quality of a given milk supply is judged. The average is determined logarithmically rather than arithmetically. By averaging the logarithms of the counts, an occasional high count has less effect in reducing the quality rating of the milk. If all the counts are high, the logarithmic average approaches the arithmetic one.

Sometimes bacteria are present which do not grow well on the particular medium used, in which case the colonies are small and hard to see. These are called *pin-point* colonies. Another cause of pin-point colonies is the overcrowding of the plates, owing to the presence of so many bacteria that in their competition for food the colonies do not develop well. Obviously the latter condition can be prevented by plating a higher dilution of the sample, yielding fewer colonies.

A comparison of counts made from milk before and after it is pasteurized will give information concerning the ability of the organisms to resist the action of heat. The decrease in the number of bacteria as shown by such counts is a measure of the efficiency of the pasteurization process. Provided that the pasteurized milk had not become contaminated after pasteurization, a higher count in it than in the raw milk indicates the presence of thermophilic organisms. This is not a common occurrence. Usually about 96 to 99% of the bacteria in raw milk are destroyed by pasteurization.

Some authorities believe that sufficient information concerning the sanitary status of a milk supply may be obtained from the reductase test and an examination for coliform organisms, combined, in the case of pasteurized milk, with a phosphatase test. A common objection to the agar plate count is that it requires much equipment and results are not obtained until after two days. In Great Britain the plate count has been abolished for the official examination of pasteurized milk and replaced by

the phosphatase test and a modified reductase test.[85] The claim is made that a wide margin of error appears inevitable in arriving at the count and more particularly, the test takes account of heat-resisting organisms whose presence is of no material significance for the safety or keeping quality of the milk.

Direct Microscopic Count

The number of bacteria in milk may be estimated by an actual count by means of a microscope. The method is called the direct microscopic count or the Breed count, after Dr. R. S. Breed, who developed the procedure.[83] The sample of milk is obtained in the manner described under the agar plate count.

For the direct microscopic count, deposit 0.01 milliliter of milk on a glass slide by means of a special capillary pipette. Spread the milk evenly over an area of 1 square centimeter. For rapid work, not to be used for official control purposes, the milk may be measured with an especially calibrated loop of platinum wire. Dry the film in a warm place, but avoid excess heat which may cause the film to crack or peel. Dip the slide for about 1 minute in xylol to remove the fat. Drain, allow to dry and then place in 90% alcohol for 1 or 2 minutes. This fixes the smear to the glass. Transfer to the staining solution (0.3 gram certified methylene blue powder in 30 milliliters of ethyl or suitably denatured alcohol. Add this solution to 100 milliliters of distilled water). Do not overstrain by long immersion. When properly done, the background of the milk film should appear faint blue.

The combined solvent, fixing and staining solution, formulated by the author and known as the Newman-Lampert Stain, may be used.[83] It is obtainable from supply houses or may be prepared as follows:

Methylene blue (certified powder) ..	1 to 1.2 grams
Ethyl alcohol	54 milliliters
Tetrachlorethane	40 milliliters
Glacial acetic acid	5 milliliters

Add the alcohol to the tetrachlorethane and warm to 70°C. Dissolve the methylene blue in the warm mixture, cool, add the

acetic acid and then filter. Dip the slides in this solution, remove, dry thoroughly and then dip in water to remove the excess stain.

The stained slide is examined under a microscope so adjusted that each field covers a known area on the smear. When the area is known, the number of bacteria per milliliter of milk can be calculated. Microscopes are available which are especially adjusted for the direct microscopic count. A field that measures 0.206 millimeter in diameter often is used. The number of bacteria in such a field is multiplied by 300,000 to obtain the number per milliliter of milk. In practice, more than a single field is counted and the average number of bacteria per field is then used to determine the bacterial count. As shown in the following tabulation more fields are counted when the milk is of low bacterial content than when many bacteria are present.

Range of individual microscopic counts per field (0.206 mm. diameter)	Number of fields to be examined
Under 30,000	60
30,000–300,000	30
300,000–3,000,000	15
Over 3,000,000	8

Relation Between Direct and Plate Counts

In the agar plate count, only living bacteria are counted since these are the only ones that can grow. In the microscopic count it is possible that some dead organisms are stained and counted, even though they do not stain as well as living bacteria. In the plate method, a group or cluster of bacteria may develop into a single colony and be counted as if the colony originated from a single bacterium. For reasons such as these, the direct count usually gives results that are from three to four times as great as those obtained by the agar plate method, but no exact relationship exists. Most of the bacterial counts reported in dairy literature are made by the plate method. If obtained by some other procedure, the method used generally is stated.

Other Information Given by Microscopic Examination

Unlike the plate count, the direct microscopic count is not useful for the examination of milk which contains fewer than about

50,000 bacteria per milliliter since such a small sample is used that it is difficult to find enough bacteria to count in such milk. The smear however may show the presence of leucocytes which would not be apparent from a plate count. The presence of large masses of bacteria in the smear usually denotes that the milk had been handled in dirty equipment. Long chains of streptococci usually are seen in milk from cows suffering from an udder infection. The experienced worker can recognize various types of bacteria in a smear and can tell whether a high bacterial count is due to an udder infection or to the use of unsterilized equipment.[86]

The Reductase Test

The reductase test[83] is the least accurate of the tests used to estimate the bacterial content of milk and gives but a very rough idea of the number of bacteria present. It is, however, the simplest of the tests and the results may be obtained within a few hours. The test is based on the fact that the blue color imparted to milk by a very small amount of the dye *methylene blue* will disappear more or less quickly according to the number and kind of bacteria present. A concentration of one part of dye to 300,000 parts of milk gives satisfactory results. The chemical reaction by which the dye is changed from the blue to the colorless form is known as reduction and is brought about by the consumption of oxygen by the growing bacteria. Another dye, known as *resazurin*[87] is sometimes used in the reductase test. This dye changes from blue to pink and finally becomes colorless. The time in which a mixture of methylene blue and milk change to the colorless form, or the resazurin mixture changes to pink, is a measure of the bacterial content of the milk, since the speed of oxygen removal depends upon the number of bacteria present and their rate of growth.

Procedure

Use sterile culture tubes, pipettes and rubber stoppers. Prepare the methylene blue solution by dissolving 1 tablet of methylene blue thiocyanate (certified) in 200 milliliters of sterile water. Tablets and other equipment needed for the test are obtainable from supply houses. Put 1 milliliter of dye solution in a sterile

test tube and add 10 milliliters of the milk sample. Place the tube in a water bath or incubator held at 37°C. After 5 minutes, invert the tube once to mix the contents. Thereafter, invert the tube every hour.

The grading of milk by the methylene blue reductase test often is done according to the time intervals given in Table 6. Resazurin reduction times average about three-fourths those of methylene blue.

TABLE 6

Grading Milk by the Methylene Blue Reductase Test

Grade of Milk	Time for Decolorization	Approximate Number of Bacteria per Milliliter
Good to Excellent	More than 8 hours	Less than 500,000
Fair to Good	More than 6 and less than 8 hours	Between 1,000,000 and 4,000,000
Passable	More than 2 and less than 6 hours	Between 4,000,000 and 20,000,000
Bad	Less than 2 hours (Often in less than 20 minutes)	Over 20,000,000

As seen from the table, the reductase test is of little value in the examination of high quality milk, which contains much less than 500,000 bacteria per milliliter. It is used for the examination of manufacturing milk, especially that used in the manufacture of cheese and evaporated milk. Factors that limit the usefulness of the reductase test include:

1. Different rates of oxygen consumption by different species of bacteria.
2. Milk constituents, such as body cells, may consume oxygen and influence the reduction time when few bacteria are present.
3. The germicidal or bactericidal effect of raw milk is not equal for all species of bacteria.
4. Colostrum, mastitis milk and milk from cows late in lactation have shorter reduction times than their bacterial content would indicate.[88]

Chapter 5

MORE ABOUT BACTERIA, MOLDS, YEASTS, CELLS AND ENZYMES

Desirable and Harmful Bacteria

The bacteriology of dairy products would be comparatively simple if it were possible to divide the bacteria found in milk into two groups; one containing the organisms which are beneficial or desirable and the other those that are detrimental. Such a division is not practicable since the same organism may act differently under different conditions. In other words, certain bacteria may be useful in one product and yet be very undesirable in another.

The streptococcus group demonstrates this difference very well. For example, *Streptococcus lactis* is not desirable in fresh milk since it causes milk to sour, but, as has been mentioned in the previous chapter, its growth is encouraged in starters used for the preparation of buttermilk, cheese and some other milk products. *S. lactis* is harmless but some other members of the streptococcus group are pathogenic. Fortunately the latter are rarely found in milk and then, as a rule, only when they are introduced by contamination from a human source.

A number of tests are known by which the bacteriologist may determine the kind of streptococci which may be present in milk or some other product. *Hemolytic streptococci,* the organisms which cause streptococcic sore throat, are detected by growing them on a special agar medium which contains blood. If hemolytic bacteria are present, a clear area is formed around the colonies, indicating that the blood in that area had been digested or hemolyzed. It is because of their ability to digest blood that the organisms are known as *hemolytic streptococci.*

The Coliform Group

A group of non-pathogenic bacteria which are undesirable in milk are the organisms which inhabit the intestinal tracts of

animals and human beings. Among these are the bacteria known as *Escherichia coli (E. coli)* after Escherich, the name of a pioneer bacteriologist; these organisms often are referred to by an older term, namely, *Bacilli coli.* Closely related to the Escherichia is another group found in water and in the soil and which are not of animal but of plant origin. An important member of this group is known as *Aerobacter aerogenes (A. aerogenes).* Organisms of the Escherichia and Aerobacter groups are called *coliform* organisms.

In the bacteriological examination of milk, the *Standard Methods* [88] defines as coliform "all aerobic and facultative anerobic Gram-negative, non-spore-forming bacteria which ferment lactose with gas formation." The term *Gram-negative* refers to a method used to classify bacteria according to the manner in which they react to a special staining procedure.

The Gram stain is named after its originator. The method is the following: the bacteria are stained with a solution of crystal violet dye, then treated with a solution of iodine and afterwards washed with alcohol. The alcohol removes the violet dye from some kinds of bacteria while others retain the color. Bacteria which retain the violet color are said to be *Gram-positive*; those which lose it are said to be *Gram-negative.* The difference may be rendered more distinct by counterstaining with another dye of a color contrasting to the original one—brown for example. No counterstain is taken up in Gram-positive organisms but it displaces the original dye in Gram-negative cells.[89]

Bacillus cereus and *B. subtilis*, spore-forming organisms sometimes associated with sweet-curd formation in milk are Gram-positive, as are *Staphylococcus aureus* and *Streptococcus pyogenes.*

The presence of coliform organisms in water from wells, rivers and reservoirs, may indicate contamination from sewage and intestinal material of human origin. Water contaminated in this manner may also be infected with typhoid organisms or other disease-producing bacteria of intestinal origin and therefore may be dangerous to use. The coliform organisms found in milk, however, usually are of animal origin and gain entrance into the milk from dust, soil, manure, feed, water or contact with dirty utensils. With very few exceptions, the coliform bacteria do not cause disease in man but their presence in milk is undesirable

because of their relationship to other organisms of intestinal origin.

Lactic acid bacteria, such as *S. lactis*, can ferment milk sugar and form lactic acid, but during the fermentation only acid and no gas is formed. A characteristic of the coliform organisms is that they form both acid and gas when they ferment milk sugar or certain other kinds of sugars. Special tests exist by which it is possible to distinguish between the individual members of the coliform group. These tests are important because if bacteria of the aerobacter group are present in milk, they indicate undesirable contamination of soil or plant origin. On the other hand, if *E. coli* is found, it may mean contamination of intestinal origin. As has been stated, this distinction is important since these bacteria may be associated with others causing typhoid fever and dysentery.

Some organisms of the coliform group are quite hardy and, occasionally, a few may survive the pasteurization process if they were present in the raw milk. If many are present in pasteurized milk it usually means that the product was held under conditions which permitted the organisms to multiply or the milk was contaminated after it had been pasteurized.

The Lactobacilli

The lactobacilli are normal inhabitants of the mouth, teeth, gastric juice and the intestinal tract of infants and young animals. Feedstuff, silage and soil also harbor the organisms and form a common source of contamination of milk with the lactobacilli. They are long, rod-shaped organisms and are very active in the formation of lactic acid in milk. Cultures of the organism are used in the manufacture of fermented milk and certain kinds of cheese.

Historically, *Lactobacillus bulgaricus* is an interesting member of this group. About the beginning of the present century the Russian scientist Metchnicoff announced that this organism was an important factor in the maintenance of a healthy condition in the intestinal tract. He claimed that the long life of certain Slavic peoples was due to their use of milk fermented with *L. bulgaricus* and *Bulgarian Milk* became a popular beverage. More recent investigations have shown that Metchnicoff was mistaken.

L. bulgaricus is not able to implant itself in the intestinal tract, that is, it does not thrive or live under conditions that exist in the human intestine. A related organism, *L. acidophilus,* can implant itself in the intestine and is used now in the preparation of acidophilus milk and other kinds of fermented milk. This subject is discussed in more detail in Chapter 10.

Yeasts

Besides bacteria, other microorganisms may be found in milk and its products. Among these are the yeasts, which are single-celled organisms, spherical or rounded in shape. They are larger

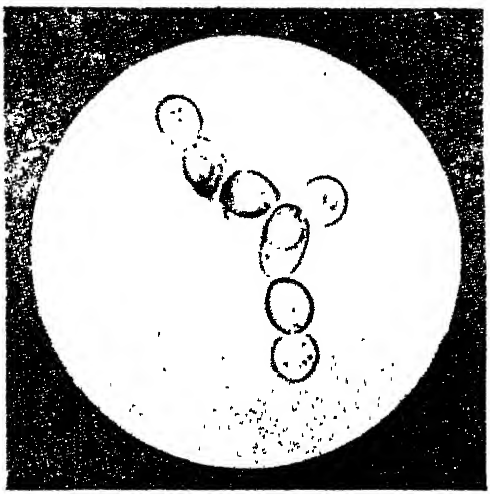


FIG. 14. *Yeast Cells, about X 2000*
(Courtesy of Fleishmann Laboratories.)

than bacteria and show a definite structure under the microscope. Furthermore, they do not reproduce by fissure or division as do bacteria, but by a process known as *budding.* When the yeast cell buds, a swelling or lump forms on its surface and gradually grows larger, finally reaching the size and shape of the parent cell. Under certain conditions, reproduction occurs by the formation of three or four spores within the yeast cell. In time the cell bursts and each spore develops into a yeast.

Yeasts are microorganisms which can ferment a solution of sugar into alcohol and carbon dioxide gas. Such a fermentation

is the basis of the rising of bread during the baking process. It is also essential to the manufacture of beer and wine. Yeasts are undesirable organisms in milk products except in cases in which they help to ripen certain types of cheese and fermented milk.

Since yeasts are present on feedstuff, in silage and in the air, their introduction into milk is almost unavoidable. They grow best in fluid products, since they need a moist environment. Old cream often has a characteristic *yeasty* odor. Yeasts that form pink colonies on the surface of milk or cream and on agar plates are rather common. A group of microorganisms related to the yeasts and sometimes called *wild yeasts* are the *torulae*. Like the true yeasts many of them can ferment milk sugar. They often are found in yeasty and gassy cream. Some varieties may cause a bitter flavor in milk, cream, butter and cheese. Yeasts and torulae are destroyed at the temperature used for pasteurization.

Butter often contains yeasts since the churn is a common source of such contamination. The number of yeasts and molds in butter often is taken as an indication of the care used in its manufacture. A low yeast and mold count generally means that the butter was made from pasteurized cream and that the manufacturing operations were conducted in a clean and careful manner.

Molds

Unlike the single-celled bacteria and yeasts, the molds are much more complicated in their structure. Usually their growth starts from a spore, which in this case is a true means of reproduction, unlike the spore of a bacterium. When the spore germinates it sends out a sprout which grows into a threadlike filament known as a *hypha* (plural, *hyphae*) from the Greek word for web. The hypha branches out to form other hyphae, so that finally a tangled, fluffy mass is formed, known as the *mycelium*. This word is derived from the Greek word for mushroom. Botanists classify molds and mushrooms in the same family, the *fungi*. The mature mold often has a distinctive color, such as blue, red, black or brown.

Practically all molds are aerobic, that is, they need atmospheric oxygen. They grow on the surface of dairy products, sometimes in a rounded, button-like form and frequently they cover the

surface with a more or less complete layer. Mildew is a familiar form of mold growth. As the mold develops, it pushes some of its hyphae into the mass of the product on which it is growing, much as a plant extends its root system in order to obtain food. Other, external, hyphae develop spores, which are the reproductive bodies or fruits. The spores are microscopic in size and are found in the air, soil, manure and on feedstuffs.

Molds need a considerable supply of moisture for growth and like the yeasts, they prefer to grow in a slightly acid medium. The acid formed in milk by the action of bacteria may reach a concentration unfavorable to the further growth of bacteria. This acid may serve as food for molds and yeasts. As they consume the acid, the decrease in acidity again favors the growth of bacteria. The bacteria that predominate in milk at this time are not acid-formers but are of the type that favor decomposition. This change from acid-forming bacteria to molds and yeasts and then to putrefactive bacteria is known as the *fermentation cycle.* Raw milk held for some time at room temperature usually undergoes this type of spoilage.

Molds are undesirable in most dairy products since they injure flavor and produce a musty odor. When growing on the surface of butter and cheese, they make the product unsightly and indicate that it is old or had not been stored in a clean place. Moldy cheese is edible; the growth is on the surface and when scraped off leaves a wholesome product. Sometimes mold growth travels along cracks into the interior of ordinary cheese and so may ruin the product. Certain kinds of molds are essential to the manufacture of Roquefort, Gorgonzola, Stilton and other special types of cheese. The mold is encouraged to grow in these cheeses because it contributes to their characteristic flavor. Often a mold culture is added during the manufacture of Roquefort and Gorgonzola type of cheese and holes are made in the body of the cheese in order to admit enough air to enable the mold to grow. Camembert and Brie cheeses are covered with a layer of mold which grows during the ripening of these cheeses.

A mold that differs from many other types often is found growing on the surface of old cream and sour milk. This mold, known as *Oospera lactis,* forms a wrinkled, velvety and almost colorless mat or film on the surface over which it grows.

FIG. 15. *Molds*

Oospora lactis, showing spores and mycelia. X 500

Yeast and Mold Counts

When the number of yeasts and molds in a product is to be estimated, use is made of the fact that they grow well in an acid medium which will not support bacterial growth. A medium, similar to that used for making bacterial counts in milk, is acidified with a small but definite amount of a non-toxic acid, such as tartaric acid.[88] The medium is placed in a Petri dish and the sample of butter or other product is added and the dish is allowed to stand for several days, usually at room temperature. During this time the growth of bacteria is suppressed by the acid and yeasts and molds present develop into typical colonies that are counted easily.

Another method sometimes used for the estimation of the amount of mold in cream and butter is known as the *mold mycelia count.*[90] The sample to be tested is dissolved in a warm, alkaline

solution containing methylene blue dye and the mixture then is passed through a cloth or cotton filter disc. The mold bodies and other insoluble matter that may be present are retained on the disc and are easily seen since they are stained blue.

The Cow's Udder and Milk Secretion

The cow's udder consists of four distinctly separate glands, known as the quarters. Each quarter is provided with a teat, the hollow, interior portion of which is known as the teat cistern.

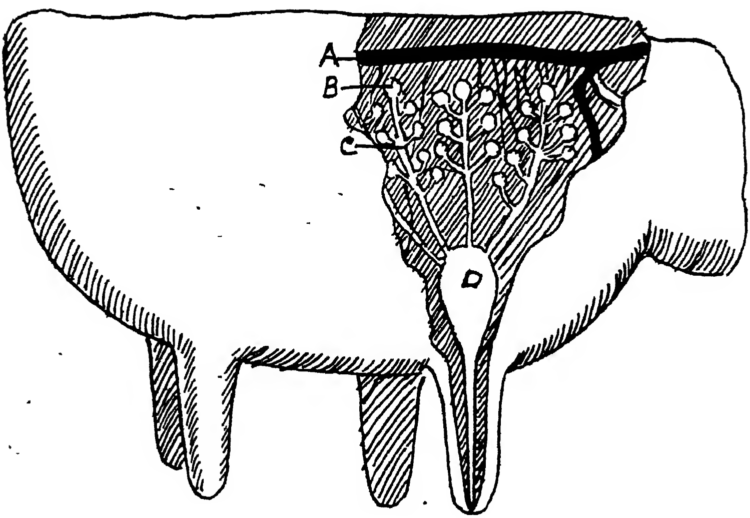


FIG. 16.

Diagrammatic View of the Cow's Udder, showing in simplified form the arteries (A), alveoli, (B), ductules, (C), and milk cistern (D). *(Courtesy of The DeLaval Separator Co.)*

The teat cistern extends upwards into the body of the gland and is connected with the gland cistern, which may vary in capacity from less than one pint to about one quart. Radiating out from the cistern walls are numerous tubes or ducts which branch out or divide innumerable times. The ducts are very small in that portion of the quarter removed from the cistern, but become larger as they approach and enter the gland cistern (Fig. 16).

Some milk secretion occurs in the lining of the ducts, but the principal secretion takes place in the alveoli, the enlargements at

the very end of each of the smallest branches of the duct system. Milk is secreted more or less continuously between milking periods. It may be slowed or stopped completely by the pressure of the milk accumulated in the alveoli. Frequent milking decreases this pressure and favors milk production. At the milking time, the cow *lets down* her milk. This is a reflex or involuntary action

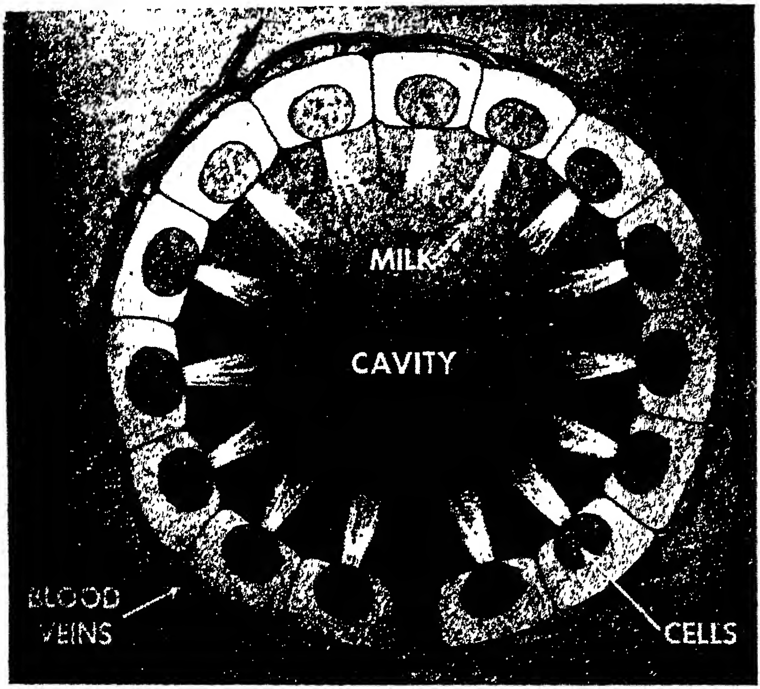


FIG 17. *Milk in the Making* (about × 2000)

This diagram shows a cross-section of the alveolus, with milk entering the cavity of the alveolus from the tiny cells which form the wall of the alveolus and in which milk is formed. *(Courtesy of The DeLaval Separator Co.)*

and is controlled by sensory nerves which carry the message to the pituitary body in the brain. This gland then furnishes to the blood stream a hormone known as *prolactin,* which, when it reaches the small muscles surrounding the alveoli, causes the alveoli to contract and thereby to squeeze the milk from them into the ducts through which it travels to the cisterns and teats (Figs. 17 and 18).

Conditions which frighten or anger the cow at milking time

interfere with the function of the pituitary body so that its hormone is not released into the blood stream and the result is that the cow does not yield her milk. Prolactin gradually is destroyed in the blood stream, and therefore the milking operation should

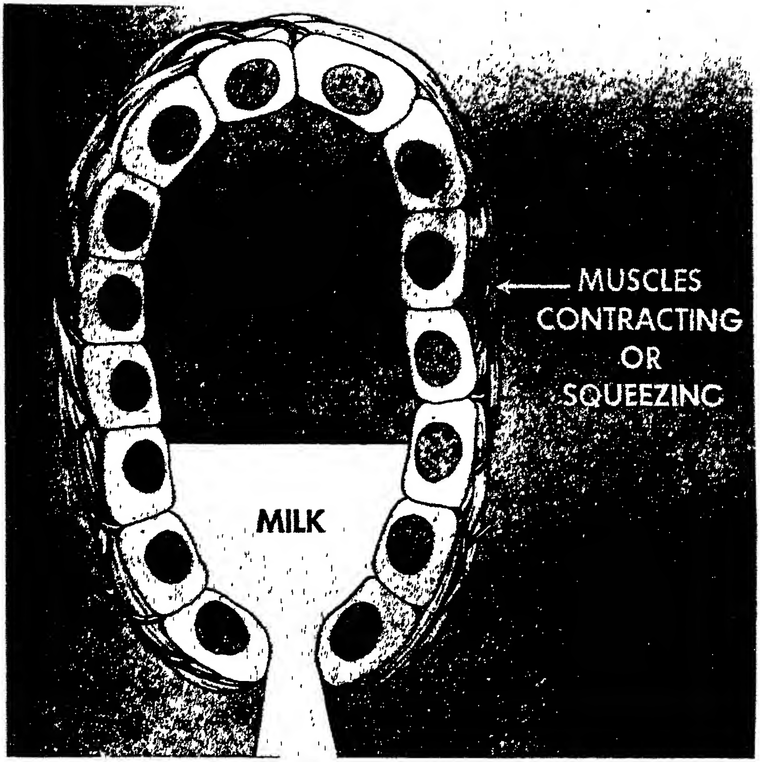


FIG. 18. *"Letting Down" the Milk*

This diagram shows how the tiny muscles which surround the alveolus contract and squeeze the milk from the cavity from which it passes to the milk cistern through the ductules. *(Courtesy of The DeLaval Separator Co.)*

be completed before its influence is lost, which is usually within 10 minutes.

Little is known concerning the actual processes by which blood constituents are changed to milk. It has been shown that milk sugar is formed from glucose, the sugar contained in the blood. Milk fat, in some unknown manner, is formed from fats that exist in the blood. Milk proteins must be formed from protein material in the blood but the method of changing blood protein into such

entirely different proteins as casein and lactalbumin is not understood.

The Cells in Milk

In the process of maintaining the functions of the body, including that of the udder, blood serum passes through the walls of the various capillaries. The red corpuscles do not pierce the capillary walls but some of the leucocytes or white blood cells do. As a result, their presence in milk is to be expected. In all body activities, gland cells and their constituent parts wear down and are eliminated in various ways. Accordingly, through the functioning of the udder, cells of various kinds are normal constituents of milk.

The cells in milk, which may outnumber the bacteria present, have no special significance, unless present in excessive numbers. In contrast to the bacteria, the leucocytes are lifeless and do not increase in number after the milk is drawn. If there is blood in the milk, red cells or erythrocytes are present and a diseased condition in the cow's udder is indicated.

Various methods are used to count the cells in the milk. The method used for the direct microscopic count of bacteria may be employed since the stained cells are readily seen under the microscope (Fig. 10). In another method, a sample of milk is placed in a small tube and whirled at high speed in a centrifuge. The sediment deposited on the bottom of the tube is removed, placed on a glass slide and then is stained with methylene blue and examined under the microscope.

There is no definite agreement as to the number of cells that may be found in normal milk. Early investigators thought that large numbers, many millions in fact, were normal. Today, it is believed that the cell content of normal milk ranges between 50,000 and 100,000 per milliliter.[91, 92, 93] Milk from cows with diseased udders has an increased cell content. A count of around 150,000 warrants checking the condition of the cow while a count of 500,000 or more indicates an abnormal condition of the udder.

Mastitis

Any inflammation of the udder is called *mastitis*. The chronic form is a common disease of dairy cattle, but is not always readily

recognized. The acute form, often called *garget,* is more easily identified since the udder appears abnormal and the milk secretion is reduced and may be tinged with blood.

A number of bacteria may cause mastitis. The streptococci, especially *Streptococcus agalactiae*, are of the greatest importance. There is no evidence that any of the streptococci usually found in cases of mastitis are of any significance to human health.[23]

A bacteriological examination of the milk is the most trustworthy test to detect mastitis.[91, 92, 93] Since this test is time-consuming, a number of less accurate but more rapid tests have been devised.[91, 94, 95, 96, 97]

Enzymes

Life would not be possible were it not for the various chemical transformations brought about within the living cells by enzymes. Enzymes are defined as organic catalysts produced by living organisms. In the laboratory, for example, strong chemicals and high temperatures and pressures are needed to bring about the same types of reactions which enzymes carry out quickly at body temperature and without the use of strong acids or alkalies.

Pepsin and Rennin

Pepsin, an enzyme found in the digestive juice of the stomach, is necessary for the digestion of protein food. Rennin, an enzyme present in the stomach lining of suckling animals, is able to curdle or coagulate milk. One part of the purified enzyme will coagulate more than five million parts of milk. A commercial preparation of rennin, known as rennet, is used in the manufacture of cheese. The amount used varies with the type of cheese being manufactured, but usually from 2 to 5 ounces of rennet is used to coagulate 1000 pounds of milk.

Several enzymes are found in milk. Many of them originate in the blood stream of the cow and apparently have no special function in the milk. Some are of bacterial origin. The activity of most of the enzymes is destroyed or greatly reduced at the temperature used to pasteurize milk. Two enzymes in milk, namely *lipase* and *phosphatase* are of special interest.

Lipase

Lipase can decompose fats. During this decomposition certain acids which have a characteristic flavor and odor are liberated from the fat. Among these is butyric acid, one of the fatty acids present in milk fat. The liberation of butyric acid by lipase action on the fat in milk, butter or cheese gives the product a rancid odor and flavor. Much of the flavor of Roquefort cheese is caused by lipase activity.

Milk obtained from cows late in their lactation period may contain an active lipase which causes the milk to become rancid. Certain bacteria also produce a lipase which is capable of creating rancidity in milk. If such bacteria are present in the raw milk, they may be destroyed by pasteurization and the development of rancidity can be prevented. Lipase also is destroyed by pasteurization, but pasteurization will not remove a rancid flavor if it is present in the raw product.

Phosphatase

The enzyme phosphatase has the ability to liberate phosphoric acid from certain of its compounds. It is present in raw cow's milk but very little is found in goat's milk. The presence or absence of phosphatase in cow's milk is the basis of a test commonly used to determine whether or not the milk is raw or pasteurized (see Chapter 17).

CHAPTER 6

THE CONTAMINATION OF MILK AND ITS PREVENTION; STERILIZATION OF DAIRY EQUIPMENT; FLAVOR; FLAVOR DEFECTS IN MILK

Contamination of Milk and Its Prevention

Bacteria in the Cow's Udder

Even though it may be produced under the cleanest of conditions, milk usually contains some bacteria at the time it is drawn from the cow's udder. The contamination of milk begins while it is still in the udder since bacteria present in the blood stream may find their way into the udder or contaminating organisms may enter from the outside through the milk ducts. The warm, moist interior of the teats and udder are favorable areas for the development of bacteria, should they be present. Harmless forms of staphylococci are the bacteria most commonly found in aseptically drawn milk but streptococci also occur very often. Organisms of tuberculosis, brucellosis or other diseases may be found if the cow is infected.[23]

The *fore-milk* or first few streams drawn from the udder usually contains a larger proportion of bacteria than the last milk, the *strippings*. However, the manipulation of the udder at the end of the milking may dislodge bacteria and cause the strippings to contain more organisms than the middle portion of the milk drawn. The elimination by the milker of the fore-milk has no practical influence upon the total bacterial count of the main bulk of the milk but its elimination is advisable since the fore-milk often may be of inferior flavor. Usually the first two or three streams of milk are discarded. This portion of the milk is of relatively low fat content.

Bacteria in the Air and Dust

The number and kind of organisms in the air may vary considerably according to the season of the year. The number of

bacteria is usually smaller in the cooler and rainy months. Comparatively few acid-forming bacteria are found in the air, but yeasts and mold spores occur frequently. Under ordinary conditions probably not more than twenty bacteria per milliliter of milk may be derived from the air.

The dust in milking barns, especially at feeding times or when the cows are being brushed, may carry enough bacteria to increase materially the bacterial count should the dust fall into the milk. Manure may enter the milk, and the bacteria contained therein grow rapidly in milk. Living organisms of bovine tuberculosis may enter milk in this way from tuberculous cows. Ordinarily, such care is taken in milking operations that actual contamination from this source may be considered to be insignificant. The number of organisms that might be added to milk from sources such as those mentioned is not nearly as large as is supposed popularly, and even under very dirty conditions, usually not more than about 25,000 organisms per milliliter get into the milk. The potential danger of such contamination, however, should not be ignored and every care should be taken to produce milk under clean conditions.

Contamination from Utensils and Equipment

In order that the bacterial count of milk may be as low as possible, it is essential that all dairy utensils and equipment be kept clean, sterilized and dried after usage. Milking machines and their parts need careful attention for they may provide a serious source of contamination if not properly cleaned and sterilized. Warm water and traces of milk left in a container provide a good environment for the growth of bacteria. It is not unusual to find enough bacteria in a can that was washed but not sterilized to add from 10,000 to 100,000 bacteria to each milliliter of milk placed in the can.

Milk Bottles and Bottle Caps

If not cleaned and sterilized before filling, milk bottles may be a serious source of contamination. They should always be capped by machine. Hand-capping brings the cap and bottle into contact with the worker's hands and fingers and thus exposes the product

to contamination. Imperfectly capped bottles should not be adjusted by hand for the same reason. The caps themselves do not contribute materially to the contamination of the milk unless they were kept uncovered in an exposed or dusty place.

A closure that covers both the top of the bottle and the pouring lip is more desirable than the ordinary bottle cap. By protecting the top of the bottle, this type of closure protects the milk from any contamination that may occur during handling or from contact with flies or animals. It also prevents contamination from the sucking back into the bottle of any milk that may have been forced out by expansion if the bottle had been held in a warm place.

Paper milk containers, whether factory made or set up in the milk plant by a special machine, are practically sterile. The square containers are so constructed that the pouring lip is protected from outside contamination.

FIG. 19. *One-quart Milk Bottles*

The glass bottles have applied designs and lettering in color. Bottle 1 is the new light-weight, stream-lined quart container. Bottle 3 has the pouring lip protected by the cap; Bottle 4 shows the hooded cap which is sealed in place. Single service paper containers are shown by 6, 7 and 8. The lid on 7 and 8 is so shaped that it protects the pouring lip.

Some Other Sources of Contamination

Everyone has long been aware of the danger of the contamination of foodstuffs by flies. Therefore, it will suffice here to emphasize the fact that flies should be prevented from entering any room where milk is handled or dairy utensils are stored.

The milker and milk plant employee in general, especially, if their hands are wet, may let drops of water which carry dirt and bacteria fall into a milk container. Pathogenic organisms may be introduced in this manner. Coughing, spitting and sneezing in the vicinity of a milk container may be another possible source of contamination.

The knowledge and the appreciation of the precautions necessary to prevent contamination and the realization by the milker and handler of their responsibility contribute greatly to the production of a clean milk supply. Laxity in any one step in the production of clean milk may cause other employees to attach less importance to regular sanitary procedures Owing to the care taken in every step of milk production, from cow to consumer, milk has become one of the cleanest foods in our diet.

The Germicidal Action of Milk

About 50 years ago, it first was noted that bacteria do not grow well in freshly drawn milk. An investigation showed that such milk has a slight germicidal action.[98] This property is retained by the milk for several hours after it is drawn and may still be present after 24 hours if the milk is held at a low temperature. A substance called *lactenin,* which has the ability to inhibit the growth of bacteria, has been isolated from milk.[99] The presence of a substance in raw milk that restrains the growth of certain strains of coliform organisms also has been reported.[100]

The germicidal action of milk is of no practical importance, aside from any restraining action it may have on the growth of bacteria while the milk is still in the udder.

Sterilization

In the dairy industry, sterilization generally means the destruction of most of the growing cells of microorganisms, rather than the total destruction of all living forms, including spores. It is doubtful whether any milk product is bacteriologically sterile. Canned, evaporated milk most nearly approaches this state, but it may contain spores, as well as a few surviving vegetative forms of bacteria.[28]

Visual examination will show whether or not a piece of equip-

ment is clean since traces of milk and grease films are readily apparent but since bacteria are too small to be seen it is necessary to follow certain accepted procedures for the sterilization of equipment.

Hot water, at a temperature of at least 170°F. and applied for not less than 20 minutes may be used to sterilize equipment.

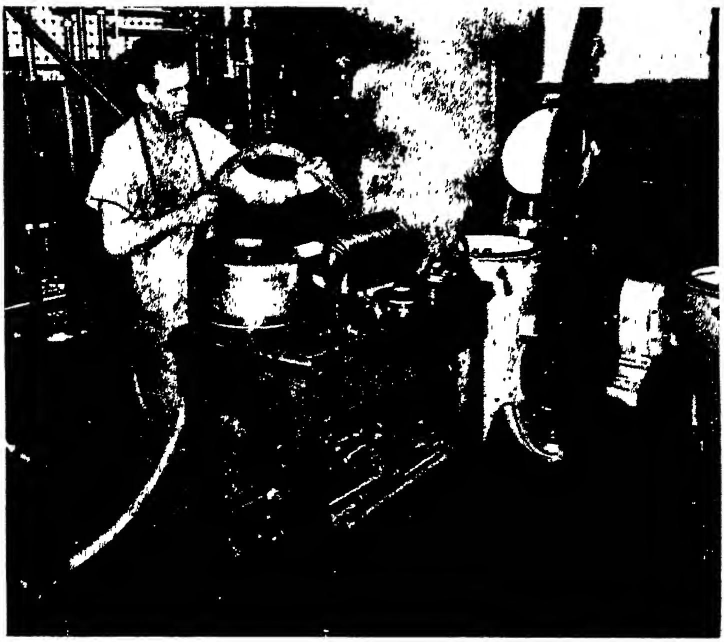


FIG. 20. *Sterilizing Dairy Equipment With Live Steam*

Here parts of a clarifier are being sterilized. Note that all pipes through which milk flows are taken down, cleaned and sterilized. H.T.S.T. pasteurizer to left; homogenizer in left background. *(Courtesy of Golden State Co., Ltd.)*

Immersion of the equipment in boiling water for at least 5 minutes is more desirable whenever it can be used. Live steam commonly is used and is a very satisfactory sterilizing agent. If applied in a closed container, such as a covered vat, steam sterilization will destroy non-spore-forming bacteria, yeasts and molds. After sterilization, equipment should be left to dry, whenever practical, since moisture favors the germination of spores and the growth of surviving bacteria.

Chemical Sterilization

Satisfactory and economical results often may be obtained with chemical sterilizing agents especially in places where it is not practical to apply heat, such as on the surface of large vats. Certain chlorine compounds are used widely, because in the dilutions used they are non-poisonous and lack objectionable odor.[101] In general, it is not advisable to depend solely on chemical sterilizers if hot water and steam are available, because certain factors detract from their effectiveness. The principal criticism against chemical sterilization and chlorine sterilization especially is that in the presence of milk residues and other organic matter their efficiency is decreased.

Alkaline solutions of sodium hypochlorite are used as well as solutions made from bleaching powder or calcium hypochlorite. Organic compounds of chlorine, such as chloramine mixtures also are employed. Proprietary chlorine compounds may be used but are expensive if their cost per pound of available chlorine is considered.

The more alkaline the solution, the more strongly the chlorine is held in chemical combination and the less opportunity it will have to exert its fullest germicidal action. A neutral or very slightly acid solution is much more effective, but loses its strength rapidly and may prove corrosive to some types of equipment.

Milk bottles and dairy equipment, in general, should be rinsed with a solution that contains between 50 and 100 parts per million of available chlorine. Rinse solutions that contain as much as 500 parts per million will not impart an undesirable odor or flavor to milk subsequently placed in the sterilized container. The amount of chlorine that ordinarily would be retained has no practical effect in reducing the bacterial content of the milk. If sufficient chlorine is present to reduce the bacterial count, the milk will develop a distinctive odor and flavor.[101]

Non-Chlorine Sterilizing Agents

Alkaline solutions, such as those made with lye or caustic soda, have definite germicidal properties. They are corrosive to many metals used in dairy equipment and are hard to rinse off com-

pletely. The use of *wetting agents* in connection with sterilizing solutions increases their effectiveness. These compounds allow the solution to cover the surface evenly and permit it to penetrate any small cracks that may be present.

Some alkaline compounds tend to form deposits on equipment, especially if the water supply is hard. The use of slightly acid detergent solutions has acquired some popularity since they prevent such deposition and also have a germicidal effect.[102, 103]

Organic compounds known as *cationic quaternary ammonium detergents* have germicidal properties and may be used to sterilize dairy equipment.[104] These compounds are non-toxic, have practically no odor and are neutral in reaction. Sufficient data about their use on a commercial scale in dairy plants is as yet not available. They are used, however, to sterilize food utensils and drinking glasses in restaurants and fountains.[105, 209]

So far, attempts to sterilize milk by use of ultraviolet light have not been satisfactory.[106] The rays are efficient only on the surface or through a very thin layer of material. Milk constituents, especially the protein, absorb the ultraviolet rays before they have any destructive effect upon the microorganisms present and a prolonged exposure to the rays gives the milk an unpleasant flavor. Ultraviolet light has been used to sterilize churns, empty bottles, the surface of packed butter and in attempts to prevent the growth of mold on cheese during storage. Its use to impart vitamin D activity to milk is described in Chapter 3.

Flavor and Flavor-Defects in Milk

Flavor of Milk

The flavor of milk may have little to do with its nutritive value, but generally it is of much importance since it controls the relish with which milk is consumed.

Taste has been defined as the impression perceived in the mouth alone, flavor as the combination of the sensations of taste perceived in the mouth with those of smell perceived through the inner nasal passages. Since it is difficult to separate these sensations, no clear distinction can be made between them in a discussion of the flavor of milk and most milk products.[107, 108] Physiologists have demonstrated that all taste reactions are due to four sensa-

tions perceptible to the taste buds of the tongue. These are sweet, sour, salty and bitter tastes. Since only substances which are in solution affect the taste buds, those constituents of milk which are not in solution, principally the fat and protein, have little direct influence on flavor. The natural flavor of milk is scarcely discernible, yet is pleasant and slightly sweet. It may be surmised that this flavor is due to the combination of sweetness, originating from the lactose, and saltiness from the chlorides and perhaps the citrates and other mineral salts present. Normal milk contains no constituent that contributes a bitter flavor. Furthermore, a sour or acid flavor also is abnormal, since fresh milk does not contain enough acid to affect the taste buds. If lactic acid is formed by the activity of bacteria, milk tastes sour to most people when the acidity reaches 0.3%. An experienced person can detect the sour flavor at 0.2% acidity.

Milk rich in lactose usually is of better flavor than milk of low lactose content and one with a natural fat content between three and five per cent generally has a better flavor than milk with a higher fat content. This is in line with the observation that as the fat content increases, the ash and lactose content decreases.

Types of Off-Flavor in Milk

Milk with an off-flavor may be safe to drink, but it will not be used as readily as milk with its normal, agreeable flavor. Many flavor defects can be detected by the sense of smell alone, especially if the milk is warm. In general, flavor defects can be divided into four groups, as described in the following paragraphs.

1. Off-flavors derived from the cow's feed are of rather common occurrence. They often are more pronounced in the cream than in the original milk. The flavor and odor imparted by alfalfa and by wild onions and other weeds is recognized easily. Workers in the College of Agriculture, University of California, showed that within a minute after a cow breathed the odor of garlic, it could be detected in her milk. An off-flavor or taint that is present in the milk of a healthy cow at the time of milking probably is not of bacterial origin.

2. The biological or chemical change that may occur after the milk has left the cow is an important cause of flavor defect. The

sour or *acid* flavor caused by the activity of the lactic acid bacteria is most common, but acidity also may be produced by members of the coliform group and other organisms. The presence of a large number of acid-forming organisms in raw milk often indicates that it had not been cooled properly or that it was contaminated through the use of unclean utensils.

Bitter flavor is commonly caused by the action of proteolytic organisms, that is, those that decompose milk protein. The decomposition products have a very bitter flavor. The flavor should not be confused with rancidity.

A *fishy flavor* is more commonly found in cream and butter than in milk since it is caused by the presence of decomposition products from substances associated with milk fat.

A *rancid flavor,* of bacterial origin, sometimes develops in raw milk. The causative organisms, known as *lipolytic bacteria* are active at a temperature below that favored by most other bacteria that may be present in milk. Lipolytic bacteria liberate a lipase which acts upon milk fat in the same manner as does the lipase found naturally in milk. Pasteurization will prevent the development of rancidity of bacterial origin since the causative organisms are destroyed easily at pasteurization temperature. If the rancid flavor is already present in the raw milk, pasteurization will not remove it. Another source of rancid flavor is described in section three, below.

The *oxidized flavor* rather often found in milk, which otherwise is of good quality, is of chemical rather than bacterial origin. This defect, also known as *cardboard* or *oily* flavor usually is found in milk of low bacterial content. Apparently it is caused by some change in one of the constituents of milk associated with the fat. The presence of a trace of copper in the milk often hastens the development of an oxidized flavor. Contact of the milk with copper equipment or equipment made with a copper alloy often is sufficient to favor the development of this defect. Recently it has been shown that the total removal of ascorbic acid (vitamin C) from milk will prevent the formation of oxidized flavor.[109] During their growth in milk, bacteria apparently produce a substance, (or perhaps remove the ascorbic acid), which protects the milk fat from undergoing the change which results in the formation of oxidized flavor. The reduction of the oxygen

content of the milk by bacterial growth may also be a factor in the prevention of oxidized flavor.

An off-flavor, very similar to an oxidized flavor, is caused by exposure of milk to direct sunlight. Milk, in a clear glass bottle, left standing in the sunlight for a few minutes may acquire this defect. Oxidized flavor, especially if caused by contact with copper-bearing equipment, develops slowly over a period of one or more days, but the *sunlight* flavor may be apparent after an exposure to light for ten or fifteen minutes.

Organisms that form *gas* in milk usually are members of the coliform group. Cultures used for the preparation of sour cream, buttermilk and cheese may become contaminated with these organisms and cause gas formation in the products made with the culture. Cream that has been held without refrigeration for several days may become gassy and foamy. As shown by the yeasty odor of such cream, this fermentation usually is caused by yeasts, especially the "wild yeasts" known as *torulae.*

3. The physical condition of the cow has some influence upon the flavor of her milk. A *rancid flavor* sometimes is present in the milk secreted by an apparently healthy cow. The flavor is detectable in the milk at the time it leaves the udder or very shortly thereafter. It is not of bacterial origin, but is caused by the action of lipase which liberates fatty acids from the milk fat. Rancid milk often is obtained from cows late in their lactation period and sometimes from cows with diseased udders. Green feed appears to favor a reduction in the incidence of rancid milk as secreted by the cow.[110]

Milk from a diseased udder often is quite salty.[111]

4. Milk may acquire an off-flavor if strong odors exist in the milking place or if the milk is held near odorous substances. The absorption of odors, however, is not as important a source of flavor-defect as is commonly believed.[112] An important exception occurs when milk is held in a refrigerator near foodstuffs that have a strong odor.

Other Defects in Milk

Ropy Milk

At times milk may acquire a viscous body and long threads of slime may be drawn from its surface, hence the name *ropy.*

Except for the development of acidity, ropy milk shows no change in its flavor. There is no evidence to show that its consumption is harmful; in fact, in Scandinavia, a fermented milk preparation actually is made with ropy milk.

The ropiness is caused by the presence of gums and mucins formed by bacteria. It is closely associated with the formation of the capsule or gelatinous membrane that surrounds the bodies of some bacteria. The defect becomes apparent after milk has been held for several hours, during which time the bacteria grow. Ropy milk should not be confused with the *stringy* milk found in some cases of mastitis or udder disease, where the viscous condition is apparent as soon as the milk is drawn from the udder.

Ropy milk often is caused by the use of contaminated water into which milk cans are placed for cooling or which is used to wash cans and other equipment. Material from wet or muddy fields which collects on the flanks and udders of the cows is another possible source of contamination Ropy milk also has been traced to infection from dusty feed, infected bedding and manure. Organisms of the coliform group and certain streptococci commonly are associated with the development of ropiness.

To control the defect, identification and removal of the source of contamination is necessary. Usually, the contamination is removed when the milk cans and equipment are properly sterilized. Before milking, the cow's udder should be wiped with a solution that contains about 200 parts per million of available chlorine. Since the bacteria concerned are not spore-formers they are destroyed readily by pasteurization. Some of the organisms may survive and cause an outbreak in the pasteurized milk but this is infrequent.[113]

Sweet Curd

Sweet curd is a coagulation of milk which occurs without any immediate increase in its acidity. It is caused by bacterial action and often appears in the form of small, coagulated particles floating on the surface of the milk, but the entire mass of the milk may coagulate or assume a jell-like body. Later, acidity may develop and then decomposition occurs, especially if the milk is held in a warm place.

Most milk may contain some bacteria capable of forming sweet

curd, but conditions usually are not favorable to their growth. These organisms form an enzyme, similar to rennin, which has the ability to coagulate milk. The defect occurs most often when the milk is held at a temperature of 104° to 109° F. The enzyme is destroyed during pasteurization, but some of the organisms may survive and become active when suitable conditions prevail.

Color Fermentation

A very unusual type of fermentation may occur in milk and cream in which bacteria cause a color to develop in the product. A red color may be formed by several harmless organisms, especially the bacterium *Serratia marcesens*, sometimes called *Bacillus prodigiosus*. The color is quite evident when the bacteria are grown on agar plates, but it is unusual for them to grow in sufficient number to color an appreciable amount of milk. The small, red spots that form on the surface of sour milk, cream and cottage cheese often are caused by the growth of certain yeasts. Blood from the udder of a diseased cow may give a red or pink color to milk, in which case the color usually is most evident in the cream layer or in the bottom portion of the milk.

A definite blue tint sometimes is present in sour milk. The color is caused by a bacterial pigment which reacts with the acid of the sour milk. The definite blue tint formed is quite different from the bluish color of milk which contains considerable added water.

Transmission of Poisons to Milk

Experiments have shown that, with very few exceptions, the administration to the cow of various drugs and poisons does not result in their appearance in the milk.[23] Among the notable exceptions are vitamin D and iodine, definite amounts of which may be found in the milk after their inclusion in the cow's feed. Traces of arsenic may appear in the milk after administration to the cow. The animal may become poisoned from the arsenic, but only an insignificant amount is transmitted to the milk.

The use of DDT as an insecticide and in fly sprays has raised the question concerning its toxicity to cows and to the consumers of their milk. In one experiment cows were fed silage that con-

tained added DDT (one pound per ton). None of the animals nor their calves showed any toxic effects from the DDT in the silage. Although the milk was found to contain 15.6 parts per million of DDT, it did not prove harmful to rats fed the milk. In another experiment, a Jersey cow was fed 24 grams of DDT daily with her feed for 157 days. This high dosage did not produce any symptoms of poisoning. Her milk, which contained 44 parts per million of DDT was toxic to rats and inhibited their growth.[114]

DDT is soluble in fats and oils and the presence of 44 parts per million in the milk would indicate that the fat separated from the milk may contain a much higher content of DDT. It is possible that butter or cheese made from milk containing DDT may be more toxic than the milk they are made from. In a recent investigation, milk fat containing 532 parts per million of DDT was separated from milk that contained 25 parts per million of DDT.[208]

Chapter 7

PASTEURIZATION: RAW MILK VERSUS PASTEURIZED MILK

Need for Pasteurization

About the latter half of the last century it was shown that certain diseases, such as typhoid fever, diphtheria and tuberculosis, could be carried from the afflicted to the healthy, either by personal contact or indirectly by the use of infected water or milk. When proper care was taken in the disposal of sewage, and water systems were safeguarded, a great advance was made in the protection of public health, but practically no attention was given to the sanitary production of milk.

The situation as it existed at the time was well described by W. T. Sedgwick who, in 1901, wrote as follows:

"Among all vehicles of infectious disease there is perhaps none more dangerous than milk. This fact is the more remarkable because milk has always been one of the most trusted of human foods. Clothed in a veil of white, associated with the innocence of infancy, of high repute for easy digestibility, believed to represent perfection as a natural dietary, popular and cheap, milk has always deservedly held a high place in public esteem."[115]

In recent years, tremendous strides forward have been made in the production of pure milk, yet in spite of the care taken, milk may at times contain disease producing organisms. The raw milk is transported in cans and tanks over long distances and opportunities for contamination may arise between the milking barn and the bottling plant which may be hundreds of miles away. In order to safeguard public health it is of prime importance that the consumer gets milk that does not contain a single harmful organism.

Often it is assumed that some of the mechanical procedures, used to prepare milk for the market, tend to reduce its bacterial content. For example, milk usually is strained or filtered through

cloth or cotton discs, but this process does not remove microorganisms. The purpose of filtration is to remove any visible particles and dirt that may have entered the milk. A new, dry filter should be used for this purpose, since a used one may serve as the breeding place for vast numbers of bacteria which are washed into the milk if the old filter were re-used. Instead of filtration, many milk plants use a mechanical clarifier to remove foreign matter from milk. The clarifier operates on the principle of the centrifugal cream separator. It is so designed that the cream is not removed from the milk, but that dirt, some bacteria and body cells are caught in the bowl of the clarifier.

Clarification is an efficient way to remove dirt from milk, but it does not materially reduce its bacterial content. It sometimes has the effect apparently of increasing the bacterial count because its mechanical action tends to break up clumps of bacteria and release the individual members throughout the milk. Filtration and clarification of milk improves its appearance, but the production of clean milk in the first place is essential. The mere removal of the evidence of contamination does not make the product clean or safe.

The only way a milk supply can be assured to be safe is to pasteurize it. Pasteurization is the name given to the process of heating a foodstuff, usually a liquid, for a definite time and at a definite temperature and thereafter cooling it immediately. The procedure is based upon the work of the French scientist, Louis Pasteur, who, between the years 1860 and 1864, noted that when beer or wine is heated for a few moments at a temperature between 122° and 140°F. there is no subsequent abnormal fermentation and souring. The process was first applied to milk products in Denmark, when cream for the manufacture of butter was pasteurized in order to destroy bacteria which would hinder the action of selected bacteria added to the cream in *starter* cultures.

Pasteurization of Milk

When applied to milk and its products, "pasteurization" means the exposure of all of the product to a heat treatment which will destroy all pathogenic organisms and nearly all other bacteria and yet not alter the flavor or composition of the product. All yeasts and molds generally are killed by pasteurization. Pas-

teurization is not the same as sterilization since it usually destroys only 95 to 99% of the bacteria present whereas in sterilization the heat treatment is sufficient to destroy completely all living organisms present.

After much investigation it was established that all pathogenic or disease producing organisms in milk are destroyed if it is heated to 140°F. for 30 minutes. The legal standards for pasteurization are based upon this fact but they usually require a somewhat higher temperature, about 142° or 143°F., as an additional safety factor.

The United States Public Health Service milk ordinance defines pasteurization as the "process of heating every particle of milk or milk product to a temperature of not less than 143°F., and holding at such temperature for not less than thirty minutes in approved and properly operated equipment." Pasteurization also includes the "process of heating every particle of milk or milk products to 160°F. and holding at that temperature or above for not less than 15 seconds." This latter method, sometimes called *flash pasteurization* is better known as *high-temperature short-time pasteurization* and commonly is abbreviated to *H.T.S.T.* pasteurization.

The exact time and temperature used for the holding method of pasteurization varies in the different states and municipalities, so that the required temperature may range from 140° to 145°F., and the holding time from 25 to 30 minutes. After the heat treatment it is essential that the product is protected from contamination and that it is cooled quickly to a temperature of about 40°F., or sufficiently low to retard the growth of surviving organisms.

Advocates of the use of raw milk claim that knowing that milk is to be pasteurized leads to carelessness in its production. This is not a valid statement since milk of high quality is sought by milk distributors. Milk, whether it is to be sold raw or pasteurized, often is produced on the same farm. The cooperation, supervision and advice the producer receives from the milk processors and from numerous state, county and local agencies assist in the production of a clean product. It is evident that since pasteurization destroys most of the bacteria present, the keeping quality of an inferior product could be prolonged by this treatment, but pasteurization itself must not be held at fault for any misuse of its original purpose, the safeguarding of a milk supply.

The procedure used to pasteurize milk may appear simple to one not acquainted with the dairy industry, but complicated engineering problems had to be solved before efficient and economical equipment became available. These problems included such factors as the design of the equipment, the kind of metal to use and the means by which the milk was to be heated and then rapidly cooled. As an example of the kind of problems that had to be conquered, foam formation may be considered. Foam on top of a vat of heated milk has a lower temperature than that of the bulk of the milk and so bacteria in the foam may not be destroyed. To insure proper pasteurization, mechanical features had to be designed to prevent foam formation or to heat it to above pasteurization temperature by means of live steam or hot air. Likewise, it is important that no leaky valves, protruding pipes or *dead-ends* or other mechanical features exist which prevent the constant flow of milk during the pasteurization process.

Methods of Pasteurization

Batch Holding Processes

As the name implies, in a batch holding process the entire lot of milk is heated to a definite temperature for a given time, usually between 143° and 145°F. for 30 minutes. The higher the temperature used, the shorter the holding period that may be employed. A holding period of 20 minutes sometimes is permitted if a temperature of 155°F. is used. However, a temperature over 145°F. is not favored since this is about the maximum temperature which will not adversely affect the flavor of the milk or tend to lower the volume of cream layer, usually called the *cream line*. If the milk is heated too high, a *cooked* flavor is imparted and the creaming ability is impaired. Since the consumer judges the quality of bottled milk by the depth of its cream layer, the milk dealer is careful not to treat the milk in a manner which would injure its cream line. Accordingly, pasteurization usually is done at about 143° by the batch-holding method and at about 160° by the high-temperature short-time method. No serious reduction in the cream line is caused by temperatures up to 162°F. when applied for 15 seconds but at 175°F. the milk acquires a distinct, cooked flavor and its creaming ability is practically destroyed.

In the batch process, the product is held in a tank or vat, often

made of stainless steel or glass lined equipment. Less modern equipment is made of tinned copper. In the *spray vat* system, water at 150°F. is forced through perforated pipes placed between the outer and inner walls of a double-walled vat. The milk is agitated by slowly moving paddles or blades suspended from and moved by a mechanism on the top of the vat. In a *coil vat* pasteurizer the milk is heated and at the same time gently agitated by a revolving coil through which hot water passes. In some installations low pressure steam is used as the heating medium, but it does not permit as easy control of the heating as does the use of hot water.

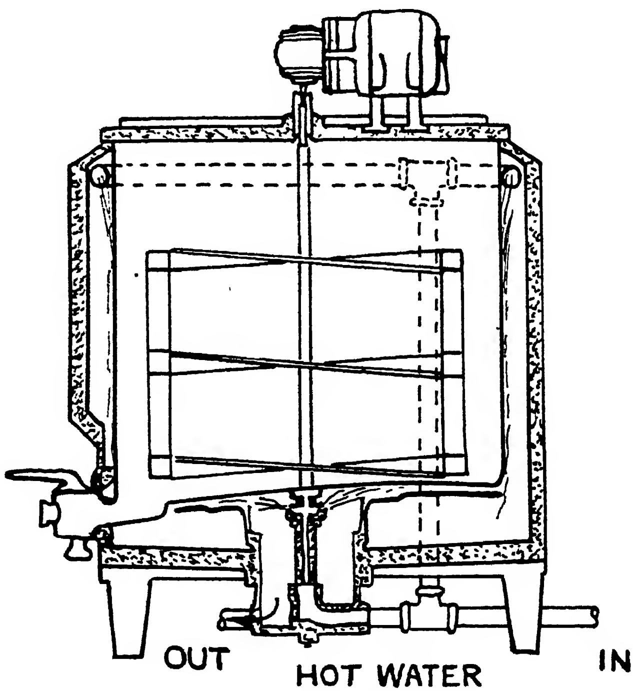


FIG. 21. *Sectional View of a Batch Pasteurizer, Showing the Spray-heating System and the Agitator*

In the *continuous flow system* the milk is impelled or pumped through a series of pipes or tanks while it is being heated. The length and capacity of the milk containers or holders and pipes is such that exactly 30 minutes are needed for the complete heating and holding procedure. A regenerative heating system gen-

erally is used. In this process, the cold, incoming milk flows over the tubes which contain the hot milk leaving the pasteurizer. Thus the raw milk is partly heated before it enters the pasteurizing unit and the outgoing pasteurized product is cooled before it enters the equipment where it is brought down to the final temperature of about 40°F. The pasteurized milk that flows through pipes is held at a pressure slightly greater than that of the incoming raw milk so that, in case of a leak in the system, the raw milk will not enter the pasteurized supply, but on the contrary, the pasteurized milk is forced to the side of the raw milk flow. This simple device prevents accidental contamination of the pasteurized milk with the raw product, should the equipment become defective.

High-Temperature Short-Time Pasteurization

High-temperature short-time pasteurization consists of heating milk rapidly to a temperature of not less than 160°F. for not less than 15 seconds. Usually the milk is held at a temperature of between 161° and 162°F. for 15 to 16 seconds. The principle of the continuous flow pasteurizer is an essential feature of high-temperature short-time pasteurization. In one method, the milk flows rapidly over the surface of flat, rectangular metal plates. These plates are criss-crossed with grooves, knobs or ripples, which direct the milk in a turbulent flow completely over the plates, so that all particles of the milk are in motion and evenly heated. On the other side of these plates, hot water flows in an opposite direction to that of the milk.

In another modification of H.T.S.T. pasteurization equipment, the cold, raw milk is heated in tubes which pass through a steam-heated cylinder. In both cases, the temperature of the milk is closely regulated by a sensitive thermometer connected to an electrical control mechanism. During the holding period, the milk is not allowed to drop a fraction of a degree below the pasteurization temperature. Should the temperature drop below this point, a valve is acted upon instantly and all of the milk in the pasteurization unit at that time is emptied into the raw milk supply. The time needed for the pasteurization process is controlled by the length and capacity of the tubes as well as the rate of speed at which the milk is forced through the equipment. Usually between

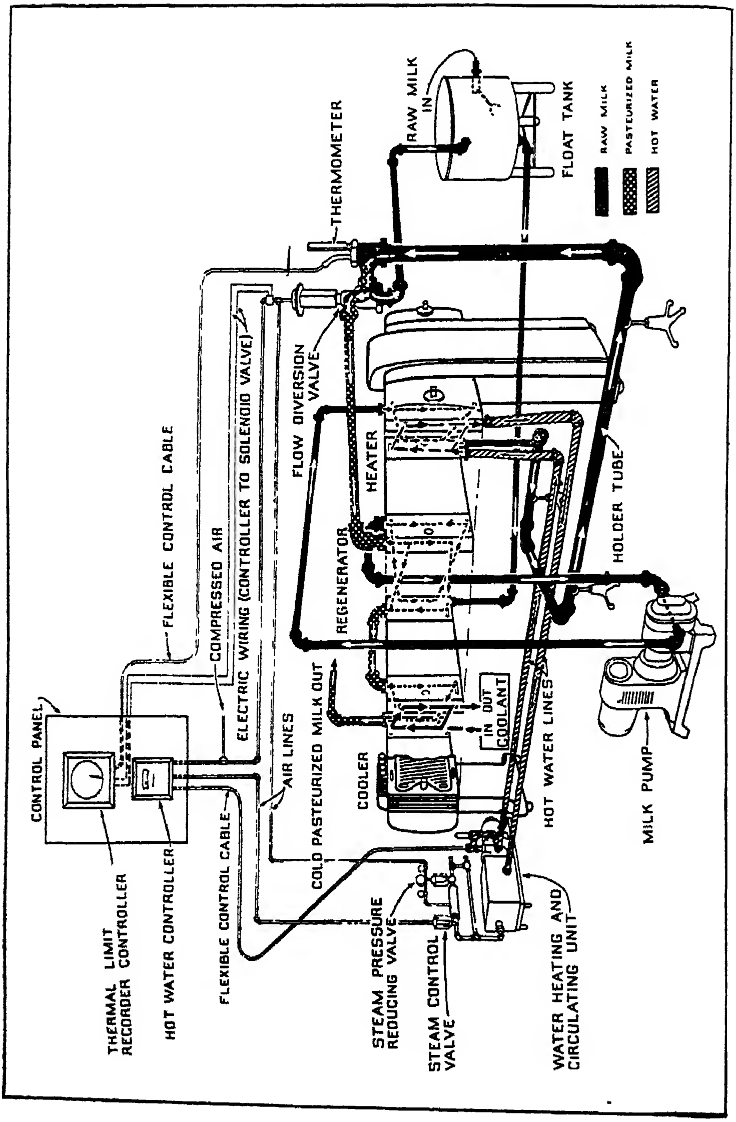


FIG. 22. *Flow Diagram of a H.T.S.T. Pasteuriser (Courtesy of The Creamery Package Mfg. Co.)*

1 and 3 minutes are needed for pasteurization by this method, counting from the time the milk is preheated until it is cooled. With the modern equipment for high-temperature short-time pasteurization this method is perhaps the most mechanically perfect now in use.

The *electropure* pasteurizer is a high-temperature-short time pasteurizer in which electricity is used to heat the milk to the

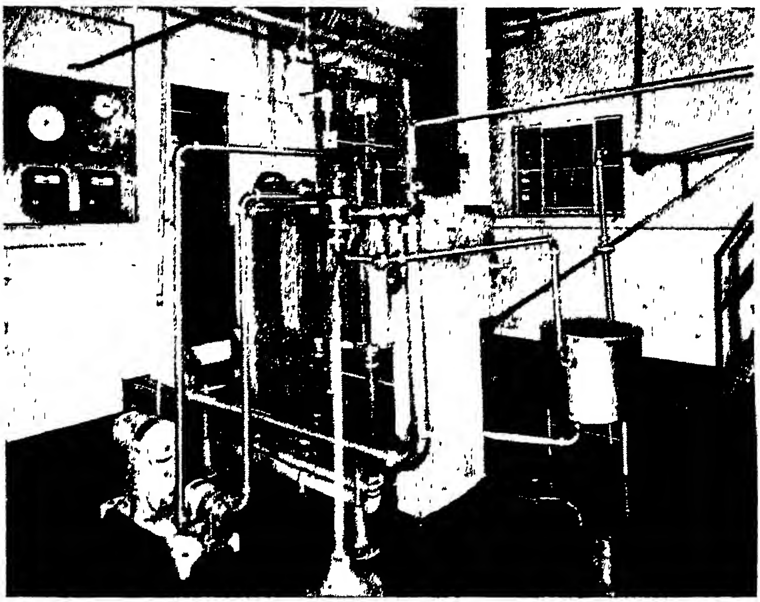


Fig. 23. *Installation of High-Temperature Short-Time Pasteurizer (Courtesy of Creamery Package Mfg. Co.)*

pasteurizing temperature. A thin film of milk is forced upwards between the walls of a narrow, rectangular chamber, the opposite walls of this compartment consist of two flat carbon electrodes. These are separated from each other by plate glass partitions. As the milk flows past the electrodes it completes the electrical circuit between them. Heat is liberated directly into the milk, which is pasteurized as efficiently as with methods where heat is applied indirectly. There is no evidence that the pasteurization is accomplished by any specific electrical effect other than the heat produced.

Heat is the important factor in pasteurization. It will be noted

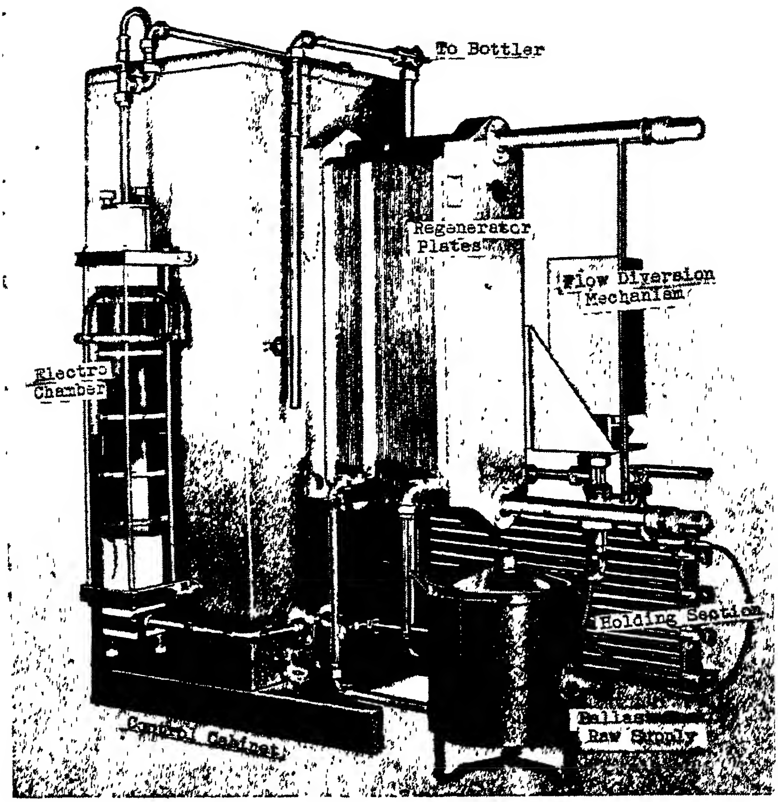


FIG. 24. *The Electropure High-Temperature Short-Time Pasteurizer (Courtesy of The Trumbull Electric Mfg. Co.)*

that by raising the temperature from 143° to 161°F., which is only an increase of 18°, the milk processor is able to reduce the time of pasteurization from 30 minutes to 15 seconds. Little is gained in bactericidal efficiency if the temperature is raised over 190°F. It has been found that about as many bacteria are killed at 190°F. as at a higher temperature.

In-the-Bottle Pasteurization

The *in-the-bottle* system of pasteurization is not used in this country, but is used to some extent in England. There the empty

milk bottles first are heated with hot water, then with superheated steam to sterilize them and finally they are filled with milk which previously has been heated to 147°F. The filled and capped bottles are then held in a vat of water heated to 147°F. for 30 minutes or the time required for pasteurization. The bottles are cooled by means of cold water. At no time does the water level in the heating or cooling procedure reach to the bottle cap. The *in-the-bottle* pasteurization system is supposed to prevent the possibility of contamination since the milk is always in the bottle until it is opened by the consumer. The difficulty of heating and cooling milk through the glass bottle adds to the cost of pasteurization, but more important is the fact that there is a possibility that not all of the milk will be heated to the proper temperature.

Vacuum Pasteurization

A method of pasteurizing cream by means of steam in a vacuum chamber sometimes is used in the manufacture of butter. The equipment was developed in New Zealand and is known as the *vacreator.* In *vacreation,* cream within a chamber under a low vacuum is flash pasteurized at 190°–200°F. by direct contact with steam. The cream then passes to another chamber where the vacuum is somewhat higher, reaching up to about 20 inches. In this chamber the cream undergoes a distillation, wherein excess steam and gases are removed. Finally the cream enters a third chamber where there is a high vacuum, about 28 inches. Here extraneous flavors and odors that may be present in the cream are eliminated, together with some water vapor. The cream leaves this chamber at a temperature of 90° to 100°F. and is then passed over a surface cooler.

Vacuum pasteurization is an efficient method to remove feed and weed flavors from cream for buttermaking. It reduces the bacterial count of the cream by over 99% and destroys all molds and yeasts that may be present.[116]

Pasteurization by Ultra-violet Light [172]

In the past, the inability of ultra-violet light to penetrate a thin film of milk has prevented its use as a means of pasteurizing

milk. Equipment able to pasteurize milk by exposure to ultra-violet light was developed in Germany during World War II. The milk is pumped through spiral units made from quartz tubing, about 125 feet in length. The tubing is housed in aluminum cylinders, about 7 feet long and 2 feet in diameter. The cylinder and its spiral is flooded with light from a series of 8 ultra-violet light tubes. Each unit has a capacity of about 100 gallons of milk per hour.

Pasteurization is best achieved by ultra-violet light in which the principal wave length is about 2537 Angstrom units. During passage of the milk through the tube a rise of about 9°F. occurs in the temperature of the milk. A slight change in flavor takes place in the milk, but it is claimed that the change is not sufficiently marked for the average consumer to notice. The ultra-violet light also increases the vitamin D content of the milk during the time of pasteurization.

Ultra-violet light pasteurization by this method is not adapted to large scale operation. Commercial utilization also must await reports on the bacteriological efficiency of the method, since such information is not as yet available.

Cooling Milk After Pasteurization

In order to prevent the growth of surviving bacteria in pasteurized milk, it is essential that the product be cooled rapidly after the heating period. Quick cooling also favors the formation of a deep cream line. Market milk and cream ordinarily are not cooled in vats agitated by paddles or coils, since agitation of warm milk favors fat separation or churning. As a rule, a countercurrent flow of milk and cooling medium is used to cool the product. Market milk plants generally use surface-type coolers, plate coolers or double-tube cooling equipment, such as those described in the following paragraphs:

Surface coolers consist of a series of horizontal tubes, usually built in two or three sections. The hot milk flows in a thin layer down over the surface of the tubes. Through the tubes of each section, the cooling medium is circulated. Cold water flowing through the upper section is used to cool the milk to about the temperature of the water. Refrigerated brine, water or another cooling medium is used in the lower section or sections in order

to cool the milk to the desired temperature. Since the cooling medium enters the bottom of each section of the cooler, the coldest milk comes in contact with the coldest section of the cooler.

Cabinet coolers consist of a series of surface coolers placed close together, thus permitting a large area of cooling surface to be installed in a small floor space.

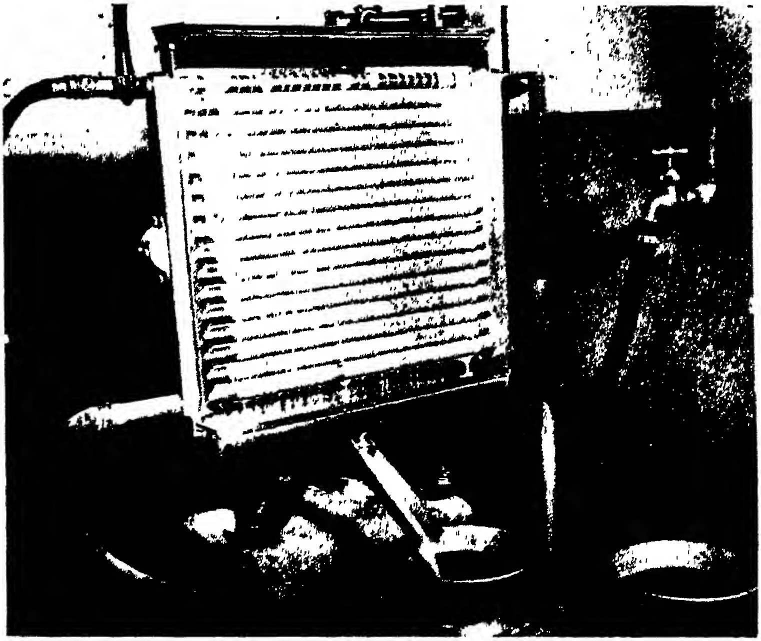


FIG. 25. *Small Surface Cooler in Use on a Farm*

Milk, from the milking barn passes through the pipe at the top, flows through a filter in the trough on top of the cooler and then over the cooler. *(Courtesy of Golden State Co., Ltd.)*

Plate-type coolers operate in much the same manner as the plate-type milk heaters used to pasteurize milk. Instead of hot water, however, cold water or refrigerated brine is circulated between the plates in order to cool the milk.

Bacteria That Survive Pasteurization

As has been shown, all disease-producing organisms that may be present in milk are destroyed when it is pasteurized, but some

entirely harmless bacteria do survive. When pasteurization first was introduced it was believed that only spores and those organisms which were able to decompose milk protein had the ability to survive the heat treatment. It has since been shown that the relative proportion of the different groups of bacteria that may

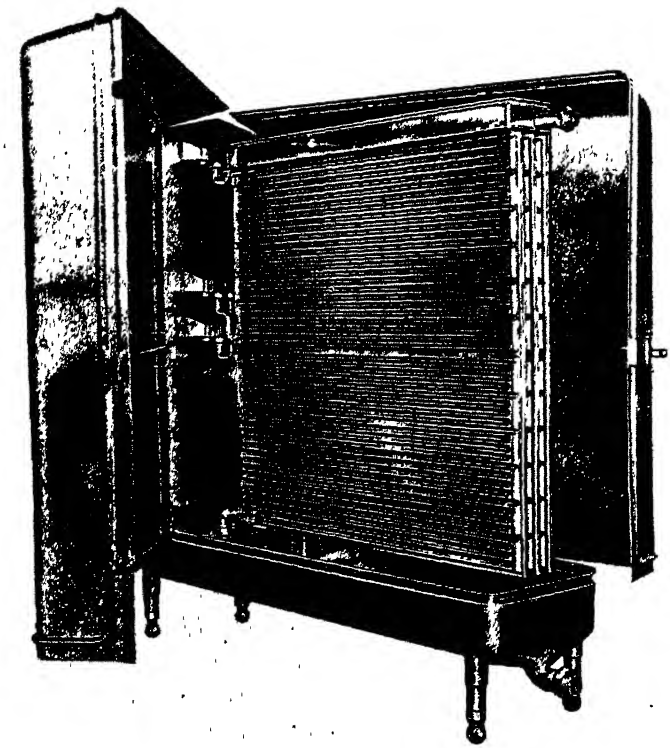


FIG. 26. *Cabinet-type Surface Cooler (Courtesy of Mojonnier Bros. Co.)*

survive in pasteurized milk is about the same as in the raw product.

The kind of bacteria found in pasteurized milk depends upon the number and kind originally present in the raw product and also upon the time and temperature used for pasteurization. In general, the higher the temperature used and the larger the number of bacteria present in the raw milk, the greater the percentage of destroyed bacteria. The age of the organisms has an influence

upon the ease with which they are destroyed by heat. Milk which has been held at a temperature favorable to bacterial growth contains many young cells which are killed more easily by heat than are older organisms. A higher heat treatment or a longer exposure to heat is needed to kill the older cells.

One of the earliest studies on the bacteria that may survive pasteurization was made in 1913 by Ayers and Johnson of the United States Department of Agricuture. They classified the bacteria into groups: *acid-forming, alkali-forming, peptonizing,* and *inert bacteria.* The peptonizing group consists of bacteria which decompose and liquefy milk protein. The inert group, as the name signifies, consists of bacteria which have no peptonizing, acid or alkali-forming properties. It was found that when milk of high bacterial count, for example, with one million bacteria per milliliter, was pasteurized, about 99% of them were destroyed. Other investigators have shown that when milk of low bacterial count is pasteurized, the number of bacteria destroyed may be not more than 86 to 90% of the original number.[117] In general, about 96% of all harmless bacteria present in raw milk are destroyed when it is pasteurized, and all of any pathogenic organisms that may be present are completely destroyed.

When milk of rather high bacterial content is pasteurized at about 143°F., the largest proportion of surviving bacteria belong to the acid-forming groups. The proportion of the peptonizing group that survives is small. Pasteurization at a higher temperature causes more complete destruction of the acid-forming bacteria and so tends to increase the relative number of peptonizing organisms that survive. This difference in the kind and number of bacteria left living explains the tendency of milk pasteurized at about 143°F. to become sour on standing because of the survival of some acid-forming bacteria. Milk pasteurized at a higher temperature for the same length of time may decompose on standing because of the survival of a greater proportion of the peptonizing bacteria.

The ability of certain strains of the Escherichia-Aerobacter groups to survive pasteurization has been made the subject of much study.[118, 119] Although they are harmless, these organisms are undesirable in milk. Some cells usually are able to survive the heat treatment and their presence does not necessarily indicate that the milk had not been pasteurized properly. It does indicate

that the milk was not produced under the most sanitary conditions.

Organisms which may cause certain flavor defects, ropiness and sweet curd have already been discussed. Provided that no recontamination after pasteurization has occurred, an increase in the number of bacteria in the pasteurized milk over that originally present in the raw milk is an indication that thermophilic bacteria are present. Some investigators [120] have found that thermoduric bacteria are not as readily destroyed by H.T.S.T. pasteurization as they are by the holder method and, if they are present in raw milk, a considerable number of the thermoduric organisms may still be found in the milk if it is pasteurized by the H.T.S.T. method. On the other hand, thermophilic bacteria have practically no opportunity to develop in the short time the milk is held at an elevated temperature in the H.T.S.T. process.

The Case of Raw Milk Versus Pasteurized Milk

The possibility of the presence of pathogenic organisms in raw milk has already been discussed and the ability of pasteurization to destroy such organisms was stressed. The potential danger of raw milk and the comparative safety of the pasteurized product is well illustrated by data accumulated by the United States Public Health Service. During the 20 years from 1918 to 1937 there were 1723 epidemics of milk-borne disease spread by the use of raw milk which caused illness to 28,221 persons and death to 869. In the same period of time, milk that had been improperly pasteurized or contaminated after pasteurization, resulted in illness of 1634 persons and death of 63. Other data on milk-borne diseases are given in chapter 8.

In its natural environment, the young mammal consumes its mother's milk in the raw or natural condition. Many people, especially raw-food faddists, take this fact as the basis for their belief that raw milk must have properties superior to those of pasteurized milk. This argument is not founded on facts, and in the following paragraphs some reasons are given to show that milk should be pasteurized and that such milk is equivalent to raw milk in food value.

A very interesting study of the nutrition of twenty thousand school children was made some years ago in Lanarkshire, Scotland.[121] One group of ten thousand received a daily ration of

¾ of a pint of milk for 4 months. Of this group five thousand children received raw, Grade A, tuberculin tested milk, the other five thousand received the same milk after it had been pasteurized. Another group of ten thousand children served as controls and received no milk. The result of this experiment was: "The effects of raw and pasteurized milk on growth and height are, as far as we can judge, equal."

Although this investigation did not escape some criticism[122] the results were substantiated by a survey in the United States by workers of the United States Public Health Service.[123] In a report published in 1932, these workers announced the results of experiments with over 3700 children between the ages of 10 months and 6 years. It was concluded that heated milk (pasteurized, boiled, evaporated and dried milk) is not inferior in growth-promoting capacity to that of raw milk, provided that the supplementary diet is that of the average American child of the age concerned.

A number of investigators have found that raw milk of good quality does not lose any of its nutritional properties when it is pasteurized, at least so far as feeding experiments with animals are concerned. An interesting observation made in one of these experiments showed that the kind of feed consumed by the cow may have a greater effect upon the nutritional value of her milk than any change that pasteurization may cause.[124]

There is general agreement among authorities that the body is capable of utilizing the calcium in either raw milk or pasteurized milk equally well, and that there is no significant difference in the retention of phosphorus and nitrogen from either type of milk. The iron and copper content of milk may be increased slightly by contact with metal equipment during the pasteurization process. The presence of copper is undesirable not only because it favors the development of an unpleasant flavor in the milk but also because it accelerates the destruction of the ascorbic acid (vitamin C) present in milk.

Vitamins A and D as well as riboflavin are not affected by pasteurization. About one-fourth of the thiamin in raw milk may be destroyed by heat treatment and about one-half of the ascorbic acid if the milk is exposed to the air during pasteurization. Vitamin C is not materially affected if the milk is heated in a closed system, free from copper. The reduction in these vitamins is not

serious since milk is not the sole food in a well balanced diet and the other foodstuffs supplement any shortcoming that may be due to a lack of certain vitamins in milk or to any possible change that might be caused by pasteurization.

CHAPTER 8

DISEASES THAT MAY BE CARRIED AND SPREAD BY INFECTED MILK AND INFECTED MILK PRODUCTS

There are a number of disease-producing organisms that may come in contact with milk and which are capable of living in it. Milk-borne diseases usually occur most frequently in children since children are the most numerous milk consumers and are more susceptible to infection. A milk-borne epidemic may start from a single source of contamination and is then often confined to those who consume the product from one dairy or are patrons of the milk distributor upon whose premises the milk was infected.

Modern sanitary measures, milk inspection, medical examination of milk handlers, pasteurization and the use of Certified Milk are accepted means for the prevention of the spread of diseases through milk. Examination of the *Reports of the United States Public Health Service* shows that most milk-borne diseases are carried by raw milk. Many of the outbreaks occur in small communities, since it is in these places that raw milk is very often consumed and the enforcement of sanitary measures may also be limited.

An interesting relationship concerning the number of disease outbreaks from contaminated milk, water and other foods is shown in the United States Public Health Service Reports. This information, summarized for the years 1938 to 1944, inclusive, is as follows:

Source	Outbreaks	Cases	Deaths
Milk	289	12,102	77
Water	305	111,839	78
Other Foods and Undetermined Sources	1645	67,706	345

Statistics on milk-borne diseases often include data on diseases which are rarely found in the United States, such as milk-borne

cases of anthrax, actinomycosis and foot and mouth disease. Although these diseases are not uncommon among cattle the danger of their transmission to man by drinking infected milk is remote. Poliomyelitis (infantile paralysis) has been claimed to be milk-borne in some cases, but in view of our limited knowledge of the disease, a considerable doubt may be justified in this regard.[125, 126, 127, 128]

The diseases spread by infected milk can be divided into two groups. In the first, one may place milk which comes from diseased cows and in the second group, milk which has become infected after leaving the cow's udder. Contamination of milk by an infected milk-handler is the most common source of milk-borne diseases. Typhoid fever, septic sore throat, and scarlet fever may be transmitted in this manner. A number of cases of dysentery have been traced to infected milk. However diarrhea and intestinal complaints, especially among children, appear to be caused by milk which contains vast numbers of bacteria, rather than with any specific infection carried by the milk.

Diseases That May Be Caused by Milk Infected While in the Udder

Brucellosis

Brucellosis is the name applied to the disease caused by members of the group of organisms known as the *Brucella.* They first were isolated in 1886 from cases of fever on the Island of Malta by Dr. Bruce, a British army officer. In man, brucellosis is also called Malta Fever, Mediterranean Fever, and Undulant Fever. In cattle the disease is often called Bang's Disease, or Contagious Abortion. Usually it is spread by contact with infected material or by consumption of raw milk from diseased animals.

In the United States, especially in the Southwest, goats infected with *Brucella melitensis* have been carriers of brucellosis. *Brucella abortus* the organism which causes the disease in cows is a common source of brucellosis in man in this country, but *Brucella suis,* the organism associated with the disease in hogs also has been found in connection with milk-borne epidemics of the disease. As often is the case with milk-borne epidemics, brucellosis most commonly is found in rural areas where raw milk commonly is used. The Brucella are destroyed easily when milk is pasteurized.

The porcine strain, Brucella suis, also infects cattle and since it is more invasive for man than Brucella abortus, the infection may be transferred by milk containing relatively few of the porcine organisms whereas milk more heavily contaminated with Brucella abortus may not transmit the infection.[129]

Brucellosis probably is of wider occurrence in man than commonly is recognized.[130] The possibility of human infection is increased by the widespread occurrence of the disease in hogs and cattle. Errors in diagnosis may conceal the infection since the symptoms include fatigue, headache, arthritic pains and night sweats. The disease normally persists for one to three months but may last for several years with intervals of normal health between attacks.

Milk Sickness

The disease of cattle known as *trembles* is called milk sickness when transmitted to human beings. Many years ago it was prevalent throughout the Mississippi Valley but is now considered a rare disease.[129] There is no record of its occurrence outside of the United States. Of historic interest is the report that Abraham Lincoln's mother died of the disease in 1819.[131]

In animals, trembles is caused by poisoning from eating white snakeroot, rayless golden rod or jimmey weed.[132] An apparently healthy cow may secrete milk contaminated with the poison.

Tuberculosis

Tuberculosis in cattle is very widespread. In many European countries it is not uncommon for thirty per cent of the dairy cattle to be infected. In the United States less than one-half of one per cent of the cows are infected with tuberculosis owing to a nation-wide program of eradicating the diseased animals.

The causative organism, *Mycobacterium tuberculosis,* is one of the most heat-resistant of the non-spore-forming pathogenic bacteria but fortunately it is destroyed by pasteurization. A cow with pulmonary tuberculosis may swallow her saliva and this, with the material coughed up from the lungs, passes through the digestive tract and remains an active source of infection. Particles of infected dust or manure may contaminate the milk or it may be infected directly from a tubercular udder.

Infected raw milk is the chief means by which milk-borne tuberculosis is transmitted to man. The feeding of skim milk and cheese whey derived from infected raw milk is a common source of tuberculosis in animals. The belief that goats are immune to tuberculosis is incorrect, since a number of cases of the disease among them has been reported.[133]

In the United States today, milk-borne cases of tuberculosis are relatively uncommon as compared to the incidence of the disease during the years when milk was not pasteurized and when tubercular cows were not eliminated from the herds.

Diseases That May Be Spread by Contamination of Milk by Extraneous Sources

Diphtheria

The diphtheria organism, *Corynebacterium diphtheriae*, may gain entry into milk if the product is handled by a diphtheria carrier. The organisms may be spread by the moisture of the breath, by coughing and sneezing or by contact with articles contaminated by infected mucous discharge. Very few cases of the disease are milk-borne.

Intestinal Complaints

The intestinal disturbance, often called *summer complaint*, evidently is milk-borne and is responsible for much illness among infants. The disorder appears more frequently among artificially fed infants than among those breast fed. It occurs chiefly in the late summer months, when the weather is warm and the bacterial content of the milk may be higher than usual. No specific organism has been found to be responsible for the complaint but this may be due to the difficulty of isolating a causative organism if it occurs only in very small numbers among the vast number of other bacteria that may be present. It has been assumed by some pediatricians that harmful or irritating substances may be formed in milk as the result of the growth of large numbers of bacteria that otherwise would be harmless. The occurrence of intestinal disorders in infants can be minimized if the milk supply is pasteurized and held under refrigeration until consumed.

Paratyphoid Fever

Paratyphoid fever is caused by organisms of the *Salmonella* group, some of which are also associated with cases of food poisoning. Paratyphoid fever may be spread by the use of contaminated milk and other dairy products. One of the rare cases in which Certified Milk was a source of infection occurred in New York in 1925. The milk concerned was contaminated by a paratyphoid carrier employed by the dairy. In 1932 an outbreak of 150 cases occurred in St. Catherine's, Ontario, Canada. This was caused when contaminated raw milk was bottled under the assumption that it had been pasteurized.

Septic Sore Throat

Septic sore throat is a severe infectious disease. Its epidemic form appears nearly always to be milk-borne and in many cases the victims are adults and adolescents. The outbreak of the disease undoubtedly is caused by contamination of a milk supply by human sources. It was formerly believed that a specific organism, *Streptococcus epidemicus* was the cause of the disease, but recent investigation shows that the organisms involved belong to the group of hemolytic streptococci known as the Lancefield A group. *Streptococcus epidemicus* is a variant of this group. The streptococci commonly associated with mastitis or garget in the cow have in no instance been associated with septic sore throat. The pathogenic organisms involved in septic sore throat are destroyed by pasteurization.[23]

Typhoid Fever

Typhoid fever is the most common of milk-borne diseases. It is caused by the organism known as *Eberthella typhosa. E. typhosa* can grow rapidly in milk held at room temperature and more slowly when the milk is held at about 40°F. It is destroyed when acid develops in the milk. Infected milk may harbor vast numbers of typhoid fever organisms without showing any noticeable change in its appearance and taste. Pasteurization is an effective safeguard against the spread of the disease

since the organism is destroyed when milk is heated for two minutes at 140°F.

Typhoid fever often may be traced to the use of raw milk which had been contaminated either by a typhoid carrier or by the use of dairy equipment which had been washed with polluted water and had not been sterilized afterwards.

A serious milk-borne epidemic of typhoid fever occurred in Montreal, Canada in 1927. At that time 4,755 persons were stricken and 453 deaths occurred. Evidently improper procedure during pasteurization permitted infected milk to be delivered to the consumers.[134] In 1944, an epidemic in California was traced to the use of soft cheese made from contaminated raw milk.[135, 136]

Food Poisoning from Dairy Products

Food poisoning, in general, may be of bacterial origin or due to the presence of poisonous substances or toxic metallic compounds in the food. Thus, certain kinds of mushrooms are poisonous and at times some shellfish contain toxic substances. The allergic reaction or intolerance to milk which occasionally is found among individuals, especially children and infants, should not be confused with food poisoning as discussed here. Some persons may not be able to tolerate milk or any preparation made from it, such as cheese, butter or ice cream. Lactalbumin and lactoglobulin, the milk proteins usually associated with the allergy, are rendered insoluble when milk is heated sufficiently, e.g., when evaporated milk is made. The insoluble proteins are inert and relatively inactive in producing allergic reactions.

Botulism, caused by consumption of food containing the toxin formed by the organism *Clostridium botulinum,* has rarely, if ever, been associated with fluid milk but has a very few times been caused by infected cheese and canned milk.[137]

Food poisoning may occur from the consumption of contaminated milk or milk product, but not infrequently, this poisoning may have its real source in other foods consumed at the same time as the milk. An outbreak of food poisoning often is associated with the use of foods contaminated with organisms of the *Salmonella* group, especially *S. enteriditis* and *S. aertryke.* A fever, in some ways similar to typhoid fever, is caused by these organisms (see paratyphoid fever). Generally it is assumed that the

Salmonella are transmitted only by milk products which have been contaminated by a human source, but there is some evidence that they may be also transmitted by an infected cow.[137]

Some strains of *Staphylococci* may be a cause of food poisoning. These organisms, especially *S. aureus*, may be present in the milk of cows suffering from acute mastitis and gangrene of the udder. *S. aureus*, which forms a yellow pigment, is often found in boils and suppurative sores. During recent years much attention has been given to the presence of staphylococcic contamination in foodstuffs as a cause of acute gastro-enteritis. Certain strains of the organisms produce a toxin which is not destroyed by ordinary heating and cooking and the consumption of food containing this toxin gives rise to an acute irritation of the stomach, causing vomiting within one-half to five hours. In many cases this is followed by diarrhea, which although violent, is not prolonged, and the attack rarely results in death. The attack soon passes and the victim may have recovered by the time an investigation is made. The rapid onset of vomiting is characteristic of staphylococcic poisoning but it does not necessarily exclude the possibility of a *Salmonella* type of infection.[137]

Often the deciding factor of whether or not a particular lot of contaminated milk may or may not be toxic depends upon the temperature at which it was held. It appears that toxin formation may be increased if contaminated milk is held at room temperature for a time, then placed in a refrigerator and again warmed to room temperature before consumption. This procedure is not unlike that followed in the home with foodstuffs not completely eaten at one mealtime.

It is difficult to demonstrate the presence of toxin in milk or other foodstuffs. Its presence can be proved only by isolation of the toxin and the appearance of symptoms after feeding the toxin-containing material to kittens or certain other animals. The widespread occurrence of several strains of staphylococci may result in their isolation from suspected foodstuffs, but the presence of toxin formation must be demonstrated to incriminate the organism. However, in an epidemic of food poisoning, any suspected food product that is grossly contaminated with staphylococci should be considered as a contributing factor.

Chapter 9

GRADES OF MILK

Milk generally is classed into grades according to the care with which it is produced. The bacterial content is used to establish the sanitary quality of the product, but, as will be shown, other factors also are considered in the grading of milk and cream. More stringent control is placed upon *market milk,* that is, milk supplied to the consumer in its fluid state than upon *manufacturing milk* which is used in the preparation of evaporated milk, cream for butter-making, milk powder, cheese and similar uses. Most health departments have sanitary codes which cover the grading of milk and cream. The Milk Ordinance and Code of the United States Public Health Service,[138] modified to fit local conditions, serves as a standard in many localities.

Dairies and farms engaged in the commercial production are visited by inspectors who regulate the various details involved in milk production. The cows should be watched for symptoms of disease and at the time of milking their flanks, belly, tail and udder should be washed free of visible dirt and loose hairs. The milking stable and the milk house usually must be built to conform to approved specifications which provide for proper sanitary conditions. All utensils and equipment which come in contact with milk during its handling, storage or transportation, should be made of approved materials, such as well-tinned metal or stainless steel. Between each period of usage, the equipment and utensils should be cleaned and treated by an approved bactericidal process, such as steam, hot water or a chemical sterilization.

Further safeguards are used in plants where milk is pasteurized. Close observation is kept over the type of equipment used to pasteurize the milk and the manner in which this equipment is employed. The time and temperature of pasteurization is watched, the accuracy of the thermometers is checked and automatic

recording charts are made to show the treatment given the milk during pasteurization.

Most states and the larger cities have established numerical standards for the bacterial count of various milk products. Cream usually is permitted to have a higher bacterial count than milk since in its separation, bacteria are carried mechanically from the

FIG. 27. *Bottling Milk in a Modern Dairy*

Equipment is made of stainless steel. Note arrangement of sanitary piping, which is taken apart, cleaned, and sterilized daily. On the far side of the glass partition the bottle-washing machines may be seen. Here milk bottles are washed, sterilized and dried. Milk bottle crates are cleaned in the crate-washers seen in the right background. *(Courtesy of Mojonnier Bros. Co.)*

milk into the cream. As a rule, two or three times the number of bacteria permitted in milk is allowed in the corresponding grade of cream. In some places an allowance is made for an increased count in milk and cream during the summer months, but this is not an approved practice. With proper care in the production and handling of the milk there should be no exceptional increase in the rate of bacterial growth during warm weather.

Owing to the various conditions under which milk is produced in different localities, it is impractical to list general standards, except for Certified Milk. The bacterial standards quoted in the following paragraphs are those suggested by the United States Public Health Service Milk Ordinance and Code.[138] Many states and municipalities have more stringent requirements and in some places the sale to the public of milk and cream below that of grade A is prohibited. As indicated in the following tabulation, milk to be pasteurized generally is permitted to have a higher bacterial content before pasteurization than the corresponding grade of raw milk.

Grades of Milk

Certified Milk

A discussion of Certified Milk is included here because of the stringent sanitary restrictions under which it is produced. These standards were devised as ideal at a time dairy sanitation had not attained the excellence now prevailing in many areas producing grade A milk.

Certified Milk is the copyrighted name given to raw and pasteurized milk produced by dairies operated according to the rules and regulations published in the *Methods and Standards for the Production of Certified Milk* issued by the American Association of Medical Milk Commissions, Inc., New York. These rules are intended to insure the purity, uniformity and adaptability of the milk for infants and growing children. The production of Certified Milk involves the veterinary examination of the cows and the sanitary inspection of the dairy farms and equipment, the medical inspection of the employees who handle the milk itself for quality and purity. This supervision is conducted under the auspices of a Medical Milk Commission appointed by the local Medical Society or other approved agency.

All cows whose milk is used for the production of Certified Milk must be free from tuberculosis, brucella infection, mastitis or any signs of other disease. The milk from any cow must not be used for a period of 45 days before and seven days after parturition. After the milk is drawn it is removed from the milking place, strained through sterilized cloths and cooled to below 50°F. Before it leaves the farm where it is produced, the milk

must be bottled, capped and sealed with a sterile hood which covers the lip of the bottle.

Each employee who handles the milk is given a complete medical examination at least once a year. Special attention is given to throat and nasal cultures and to the detection of communicable disease, especially typhoid fever, paratyphoid fever and dysentery.

Although great care is taken to protect the quality of Certified Milk, it is not absolutely free from the possibility of transmitting pathogenic organisms. At least two epidemics are recorded which were traced to its use. One of these was an outbreak of paratyphoid fever, the other an epidemic of septic sore throat. These occurred in 1925 and 1926 and it is very worthy to note that no milk-borne epidemic has been traced to the use of Certified Milk since that time.

The standards for Certified Milk require that it shall contain not over 10,000 bacteria per milliliter, and not more than ten coliform organisms are allowed to be present in a like amount. The milk may be pasteurized on the farm where it is produced but only in equipment used for no other purpose. The pasteurized product shall contain not more than ten thousand bacteria per milliliter before pasteurization and not over five hundred after pasteurization and at the time of delivery. Fewer than one organism of the coliform group should be present per milliliter of pasteurized product.

The milk is examined at least once a month for the presence of hemolytic streptococci and organisms of the coliform group. The total bacterial count is made according to the Standard Methods of Milk Analysis, but a modified medium is used for the agar plate count.

The fat content is not standardized but the milk must contain an average of 4.0% of fat, with a tolerance for the average of plus or minus 0.2%.

Vitamin D Certified Milk is milk made antirachitic by feeding irradiated yeast to the cow or, by irradiation of the milk, or by addition of a concentrate of the vitamin.

Guaranteed Milk

Guaranteed milk is not included in the grades of milk provided for by the United States Public Health Service Milk Ordinance

and Code, but it is produced in a number of localities. The conditions regulating its production are similar to those required for Certified Milk, except that the local Board of Health rather than a Medical Milk Commission has the supervision.

Grade A Raw Milk

This is raw milk with an average bacterial content, as measured by the agar plate method, not to exceed 50,000 per milliliter, or an average direct microscopic count which does not exceed 50,000 per milliliter if clumps of bacteria are counted or 200,000 per milliliter if individual organisms are counted, or an average methylene blue reduction time of not less than eight hours. If the milk is to be pasteurized, the plate count should not exceed 200,000 per milliliter, the direct microscopic clump count 200,000, the direct count on individual organisms 800,000 and the reduction time should not exceed six hours. The milk must be produced under specified sanitary conditions.

Grade A Pasteurized Milk

This is grade A raw milk of the quality described in the previous paragraph, which has been pasteurized, cooled and bottled in a milk plant conforming to required sanitary regulations. At no time after pasteurization and until delivery must the bacterial count exceed 30,000 per milliliter.

As an example of the more rigid requirements made by various control agencies, the Agricultural Code of the State of California requires that grade A raw milk shall contain not more than 15,000 bacteria per milliliter. If the milk is to be pasteurized it shall contain not more than 75,000 bacteria per milliliter before pasteurization and not more than 15,000 after pasteurization.

Grade B Milk

Grade B raw milk is raw milk which violates the bacterial standard or certain provisions for the production of grade A raw milk. It conforms with other requirements for grade A raw milk and has an average bacterial plate count not exceeding 1,000,000 per milliliter, or an average direct microscopic count

not exceeding 1,000,000 if clumps are counted, or 4,000,000 per milliliter if individual organisms are counted, or an average reduction time of not less than 3½ hours.

Grade B pasteurized milk is pasteurized milk which does not conform to the bacterial standard for grade A pasteurized milk or certain of the regulations for its production. It is made from raw milk of not less than grade B quality and has an average bacterial plate count after pasteurization and before delivery not exceeding 50,000 per milliliter. In many places the retail sale of grade B or lower grades of milk is prohibited.

Grade C Milk

Grade C milk is produced under such inferior sanitary conditions that it violates any of the requirements for grade B milk.

Chapter 10

CULTURES; FERMENTED MILKS

Cultures

About 1860, creameries in Denmark and Holland began to add buttermilk to cream in the attempt to hasten its souring and to control the flavor of the butter to be made from the cream. If the proper organisms happened to be present in the buttermilk, the desired effect was obtained. On the other hand, if gas-forming or proteolytic bacteria were present, the butter would be defective or spoil quickly. Dairy scientists sought a solution to this problem and, in time, developed the use of cultures or starters which are capable of producing desirable flavor, aroma and acidity in milk or cream and in the butter or cheese made from them.

Ordinarily, a culture as purchased does not contain enough actively growing bacteria to ripen a vat of milk quickly and so it is used to inoculate about a quart of milk or skim milk, previously sterilized or heated to a high temperature in order to destroy bacteria that it might contain. The inoculated milk, known as the *mother starter* is held overnight in a warm place or incubator in order to encourage active growth. The ripened mother starter often is transferred to a larger quantity of pasteurized or sterilized milk, which then is ripened to make a *second starter.* Sometimes the process is carried on for a third or even a fourth starter. The continued transfer through several lots of milk increases the activity and rate of growth of the original culture.

The taste and odor of a culture is not a reliable test of its quality since its acidity may mask the true flavor and aroma. A starter should have a clean, acid flavor and a firm, smooth body. A bitter taste or a lumpy, gassy or ropy body indicates the presence of an undesirable contamination.

The predominating organism in a butter culture usually is *S. lactis* but other organisms often are present. The formation of lactic acid prevents the growth of undesirable bacteria in the

milk during fermentation. Work done at the Iowa State Agricultural Experiment Station and elsewhere has shown that *Streptococcus citrovorus* and *Streptococcus paracitrovorus* are of importance in butter cultures.[1-9] These organisms do not only produce lactic acid but act also upon some of the milk constituents, especially citric acid, to form a small amount of biacetyl and related compounds. Biacetyl has a very pronounced odor and as little as 0.0002% of it is sufficient to give butter its characteristic aroma. In some localities the consumers prefer a mild-flavored butter made from sweet cream, in which case a starter is not used during its manufacture.

Starters fulfill a number of functions in the preparation of fermented milks and in the manufacture of some varieties of cheese. The acidity they produce helps rennet to coagulate the milk in cheesemaking. Cultures that contain *Streptococcus thermophilus* and other special types of bacteria are used in the manufacture of Swiss and other kinds of cheese. The flavor and texture of a cheese depend to a large extent upon the activity of the organisms introduced by the starter.

Fermented Milks

Fermented milks were used by the people of Eastern Europe and Asia Minor long before the discovery of bacteria. The basis of a fermented milk is a lactic acid fermentation but special types of bacteria and yeasts produce the typical characteristics of the fermented milks used in various parts of the world. There are two principle kinds of fermented milk: the acid type such as acidolphilus milk and the kefir type, in which a combined acid and gassy fermentation takes place. In the latter case a mild alcoholic fermentation also occurs.

It has been demonstrated that an acid milk is somewhat more easily digested than ordinary milk. It makes little difference whether the acidity is the result of bacterial activity or whether an acid is added artificially, as in the preparation of some infant foods. Fermented milks have been used for their possible therapeutic value in cases of stomach and intestinal disorders, a use based upon the assumption that the acid-fermenting bacteria and the lactose in the milk are able to create conditions in the intestinal tract which are unfavorable to the growth of putre-

factive bacteria. Putrefactive organisms favor the decomposition of protein material and the formation of gas and an alkaline reaction in the large intestine which condition may be associated with the formation of substances which cause a so-called *auto-intoxication*. Only certain strains of the lactobacilli are able to implant themselves in the intestinal tract.

It often has been assumed that pathogenic organisms cannot survive in contaminated fermented milks on account of their high acid content. The United States Public Health Report for 1945 cites an outbreak of gastroenteritis caused by *Staphylococcus aureus* in buttermilk placed in unclean containers, and experimental work has demonstrated that various pathogenic organisms can survive for several weeks in femented milks of high acidity.[141]

Cultured Buttermilk

Owing to variations in the churning process during the manufacture of butter and differences in the quality of the cream churned during various parts of the year, a uniformly high quality of genuine buttermilk is not always obtainable. To supply the demand for the beverage, a large amount of cultured buttermilk, sometimes called *artificial buttermilk* is made by the fermentation of milk or skim milk with lactic acid bacteria. Usually skim milk is used, but a small amount of cream may be added to improve its flavor. During recent years churned cultured buttermilk has become popular.[140] In this product, small particles of butter are obtained by churning the fermented milk, which usually contains between one and two percent of fat. Particles of butter may be added to cultured buttermilk by actually spraying melted butter on the surface of the milk while it is under agitation; this modification of churned buttermilk is known as *flake buttermilk*. More than the usual amount of color is commonly added to the milk before churning or to the melted butter in order to give a deep yellow color to the particles of the butter so that they may be easily seen in the buttermilk.

The pasteurized milk used for the preparation of cultured buttermilk is inoculated with the starter and held at a temperature of about 70°F. until the desired acidity is reached. This usually is between 0.6% and 0.8%, expressed as lactic acid. Often a little common salt is added to improve the flavor. When legal

regulations do not prevent its use, a small amount of gelatin or a similar substance may be added to give the buttermilk a smooth body, prevent the separation of whey and so improve the appearance of the product. The acid developed during the ripening process coagulates the milk and the churning process breaks the coagulated casein into fine particles. When the buttermilk does not contain a stabilizer such as gelatin, the fine casein particles gradually settle as the product stands, leaving a layer of more or less clear whey on the buttermilk. The presence of gas bubbles, a sharp acid odor or an excessive amount of whey indicates that the buttermilk is contaminated with undesirable organisms.

The composition of buttermilk is discussed in Chapter 11.

Sour Cream

Sour cream is a favorite milk product among the people of Central Europe and the Slavic nations. It has various uses, such as salad dressing, a spread for bread and mixing with cheese and other foodstuffs. It is made by ripening cream with a lactic acid-forming starter, cream of about 20% fat content usually being used. The finished product contains about 0.6% acidity and should have a clean, acid flavor and a smooth, thick body, free from lumps.[142]

When legally permissible, a thickener such as gelatin or sodium alginate is sometimes added in order that the cream may have a heavy body and smooth appearance. The cream may also be homogenized to increase the viscosity, or a little rennet may be added to give the cream a smooth, thick body. These procedures make the product appear richer than it normally would on the basis of its actual fat content.

Acidophilus Milk

Acidophilus milk is milk that has been inoculated with a pure culture of *Lactobacillus acidophilus* and has been allowed to ferment under conditions that favor the growth and the development of large numbers of the organism. A product that contains more than 200 million organisms per milliliter is obtainable commercially.

Care must be taken not to contaminate either the culture or the fermenting milk since *Lactobacillus acidophilus* forms acid rather slowly and may therefore be unable to overcome a contamination with other bacteria. It is necessary to sterilize the milk before inoculation in order to remove the possibility of contamination from this source. The best flavor is obtained when between 0.8 and 1.0% of acid is developed.

Acidophilus milk therapy is recognized by the medical profession and by dietitians as a practical way to introduce large numbers of the organism into the intestinal tract. It has been found to be of some use in the treatment of certain intestinal disorders, such as constipation and colitis, but authorities differ in their opinion concering its actual value. The therapeutic action of the milk is believed to be due in part to the activity of the bacteria that reach the lower intestinal tract and not entirely to the acidity of the milk.[143]

The type of bacteria that inhabit the intestinal tract is influenced by the implantation of *L. acidophilus* which in the presence of lactose brings about an acid condition in the lower intestine by reacting with the unfermented lactose. This increase in acidity favors the destruction of bacteria of the putrefactive type, which often cannot tolerate an acid environment. One pint to one quart of acidophilus milk per day usually is taken. It is often recommended that about two ounces of lactose also be taken, especially if a laxative action is desired.

L. acidophilus is one of the organisms often found in the mouth and some investigators have claimed that it is associated with decay of the teeth but nothing definite has been established to prove this assertion. One authority[144] stated, "—there is no evidence to indicate that feeding the organisms, as in intestinal therapy, need influence in any way the development or the course of dental caries."

Bulgaricus Milk

Lactobacillus bulgaricus is used in the preparation of a fermented milk of high acid content. The method of manufacture is similar to that used for acidophilus milk. Bulgaricus milk has been used in the treatment of intestional disorders but since the organisms do not implant themselves in the intestinal tract, the use of acidophilus milk is favored.

Kumiss

Kumiss is the typical fermented milk drink of Russia and western Asia. Genuine kumiss is made from unheated mare's milk, which imparts a characteristic flavor to the product. The high lactose content of mare's milk also favors an alcoholic fermentation by lactose-fermenting yeasts. Various other lactic acid-forming organisms, such as *S. lactis* and *L. bulgaricus* also are present.

The yeasts ferment a part of the lactose to alcohol and carbon dioxide gas. Since the fermentation is done in an open vessel, most of the gas escapes. The alcohol content varies with the degree of fermentation and may reach 3%. In some Siberian and other Asiatic places a brandy-like alcoholic drink is distilled from kumiss.

Yogurt

Yogurt is the Turkish name for a fermented milk of the lactic acid type. It is known by different names, according to the place where it is made; for example, in Armenia it is known as Matzoon; Leben in Egypt, Gioddu in Italy and Dadhi in India.

In the preparation of yogurt, the milk is boiled, cooled and then inoculated with a culture of lactic acid-forming organisms, especially *L. bulgaricus, B. yogurtii* and *S. thermophilus.* The ordinary lactic acid organism, *S. lactis,* may be present but it does not appear to be essential to the production of yogurt. The action of the various organisms produces 1 to 2% acidity in about three hours. Yogurt usually is eaten like a junket or custard, and may be flavored to suit the taste.

Taette Milk

Taette milk or Taetemjolk (tight milk) is used by the Scandinavian people. Milk is fermented with a *rope* forming variety of *S. lactis*. The final product is acid and slimy. A similar product made by the Finns is called *Filli*.

CHAPTER 11

HUMAN MILK; GOAT'S MILK

Human Milk

Human milk differs considerably in its composition and properties from cow's milk.[145] Especially notable are its low casein and mineral content, high lactalbumin content and the large amount of lactose present. Differences in the fat also exist; human milk contains none or very little of the fatty acids characteristic of cow's milk. According to Hilditch and Meara (see Table 29), human milk fat, so far as the fatty acids are concerned, resembles a typical margarine fat blend rather than the fat of cow's milk. The pH of human milk is about 7.0 as compared to 6.6 for cow's and goat's milk. The average composition of human milk is given in Table 7; the composition of the ash in Table 8. The vitamin content is given in Table 5.

TABLE 7

Average Composition of Human Milk

Water %	Protein %	Fat %	Lactose %	Ash %
87.80	1.73	3.40	6.83	0.24

TABLE 8

Composition of Ash of Human Milk

Calcium %	Magnesium %	Sodium %	Potassium %	Phosphorus %	Chlorine %
10.4–13.3	1.2–1.8	21.7–24.5	6.6–8.6	6.5–9.2	16.3–19.7

The practice of diluting cow's milk with an equal volume of water for infant feeding is based on the fact that the protein content of cow's milk is about twice that of human milk. It has been shown that the essential amino acids, except tryptophane and methionine, are present in human milk in just about one-half the amount present in cow's milk (see Tables 7 and 32). The

curd tension of human milk is zero.[146] Certain acids, such as butyric and caprylic acids, found in the fat of cow's milk are not present in human milk (see Table 29).

Traces of copper, iron and zinc are present in amounts comparable to those found in cow's milk. The sugar, lactose, is the same as that in the milk of other mammals, but traces of two other sugars, allolactose and gynolactose, are stated to be present also.[17] Human milk is relatively rich in amylase, the enzyme capable of digesting starch. Only mare's milk approaches it in the amount of amylase present. As shown in Table 3, human milk approaches mare's milk in its composition more closely than that of any other mammal. It has been reported that the amount of amylase in the milk decreases during menstruation and that at this time a toxic substance is present in the milk which may cause distress to the suckling.[147]

In some hospitals, human milk is obtained from nursing mothers and is stored for use by infants who for one reason or other cannot be nursed by their mothers. Usually the milk is stored in a refrigerator but in some cases it is put into small cans and then sterilized for future use. In a few instances the milk has been dried.

Infants assimilate their mother's milk more readily than that from any other source. Whenever possible it is a distinct advantage to the child to be breast fed, since this gives the child a better chance of survival through its first year of life than does artificial feeding.[148] However, human milk may be overrated in its nutritive value, since it may vary greatly in quality and fall short of the infant's requirements.

In 1934, the Journal of the American Medical Association, published the results of a study of the disease and death rate of 20,061 infants. The results are given in Table 9.

TABLE 9

Disease and Death Rate Among Infants

	Disease Rate	Death Rate
Breast fed (48.5%)	37.4	6.7
Partially breast fed (43.0%)	53.8	27.2
Artificially fed (8.5%)	63.6	66.1

The rate indicates the number of cases of disease or of deaths per thousand infants. Only 265 or 8.5% of the infants studied

were artificially fed, but their death rate was ten times as high as that of breast fed infants.[210]

Healthy infants are able to assimilate more phosphorus and calcium from breast milk than from cow's milk. Although its vitamin D content is low, the high lactose content of human milk may be a factor in the low incidence of rickets among breast fed infants. Lactose in the diet tends to increase the acidity of the intestinal tract and so creates a condition which favors the assimilation of calcium.

The vitamin content of human milk, as indicated in Table 5. is similar to that of cow's milk, except that the riboflavin content is lower and the ascorbic acid content higher. If the mother includes a vitamin D supplement in her diet, her milk will contain an increased amount of this vitamin.

At various times the question concerning the effect of smoking by the mother upon the suckling infant has been discussed. A recent investigation showed that the amount of milk secreted apparently is not affected by smoking. Nicotine was found in the milk of all mothers who smoked, whether it was only one or more than twenty cigarettes per day. However, in no case was there any evidence that the nurslings were affected by the quantity of nicotine they ingested. As a conclusion, it was stated that while the presence of nicotine in the milk may not cause demonstrable effects in the infant it cannot do the child any good.[149]

Goat's Milk

Although there are more than one million milk goats in the United States, the production of goat's milk here is not as important an industry as it is in southeastern Europe and other parts of the world. Many of the short-haired goats produce but little milk but the better type of Swiss goats, especially the Saanen and Toggenburg breeds, give four to six quarts per day. This milk approaches in its composition that of Holstein cows. The Nubian goat produces milk of high fat content, similar to that of the Jersey cow.

Goat's milk is almost always white in color, since it contains little carotene, the yellow pigment which is converted in the body into vitamin A. Although lacking in carotene, the milk is as good a

source of vitamin A as is cow's milk since the deficiency in carotene is compensated for by the presence of the vitamin itself.

The small size of the fat globules in goat's milk is one of its chief characteristics. This makes it impractical to obtain cream by allowing the milk to stand, since the fat rises slowly and in small amount. However, goat's milk may be separated without difficulty in a cream separator. The average chemical composition of goat's milk is very similar to that of cow's milk, as is shown in Table 10.

TABLE 10

Average Composition of Goat's Milk[145, 150]

Water %	Fat %	Protein %	Lactose %	Ash %
87.37	4.00	3.00	4.84	0.79

The fact that goat's milk-fat contains about twice as much each of capric, caprylic and caproic acids as does cow's milk has been claimed to be a reason for the characteristic odor and flavor sometimes associated with goat's milk.[145]

Goat's milk may be utilized for practically every purpose for which cow's milk is used. It is often recommended for infants and invalids since the milk forms smaller and more flocculent curds in the stomach and therefore may be more easily tolerated than cow's milk. Recent investigation has indicated that goat's milk is more slowly digested than cow's milk.[146] The curd tension of goat's milk is about 30 to 40 grams and is therefore about 30% softer than Holstein milk and about 50% softer than Jersey milk.[150]

Much cheese, especially in Europe, is made from goat's milk. Neufchatel and Roquefort cheeses often are made wholly or in part from it. Such cheese has a different flavor than that made from cow's milk, primarily on account of differences in the fatty acid content of the milk fats. The fatty acid content of the milk fat of various mammals is given in the appendix.

The vitamin content of goat's milk is essentially the same as that found in cow's milk.[150, 151]

Canned, evaporated goat's milk is made commercially in the United States. The composition of one sample is given in Table 11.

TABLE 11

Composition of Evaporated Goat's Milk

Water %	Fat %	Protein %	Lactose %	Ash %
74.91	7.20	8.04	8.40	1.55

Chapter 12

CREAM; SKIM MILK; BUTTERMILK; WHEY

Cream

Composition of Cream

Cream is defined by the United States Department of Agriculture as "that portion of milk, rich in milk fat, which rises to the surface of milk standing, or is separated from it by centrifugal force. It contains not less than 18% of milk fat and not more than 0.2% of acid-reacting substances, calculated as lactic acid."

Two grades of cream usually are available to the consumer, *light*, and *whipping*. Light cream also is known as *table* or *coffee* cream and the whipping cream as *heavy* or *pastry* cream. The approximate chemical composition of cream of different fat contents is shown in Table 12.

Table 12

Approximate Composition of Cream

	Fat %	Protein %	Lactose %	Ash %	Water %
Light Cream	19.00	2.94	4.05	0.60	73.41
Whipping Cream	36.00	2.20	3.15	0.46	58.19

Gravity separated cream is cream which has risen naturally to the surface of milk. It has a fat content that varies from 10 to 28%.

By means of a special type of cream separator it is possible to prepare cream of 65 to 83% fat content. This product, known as *plastic cream*, has a heavy body, and when the fat content is about 80% or more, its composition is about that of unsalted butter.

The Cream Separator

The ordinary cream separator is essentially a bowl capable of being rotated at a speed of 3,000 to 20,000 revolutions per minute.

The bowl consists of a series of conical discs which are separated from each other by projections upon their surface. Milk enters the machine through holes placed near the center of the discs. As the bowl revolves, the cream, being lighter than the milk or skim milk portion, is driven by centrifugal force towards the center of the bowl, while the skim milk is directed outwards. Since the space between the discs is small in relation to the length over which the cream must pass, ample time is secured for the cream to rise or separate before it reaches the center of the bowl

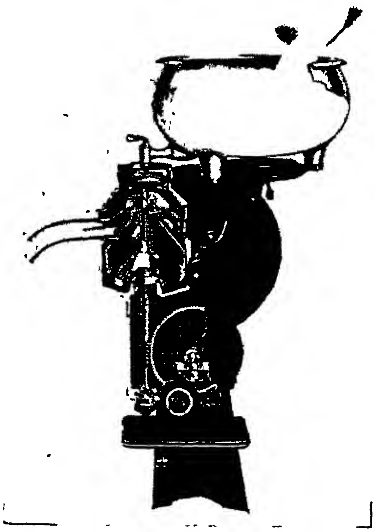


FIG. 28. *Sectional View of a Small Cream Separator (Courtesy of The DeLaval Separator Co.)*

from which it flows out. An efficient separator will produce skim milk that contains as little as 0.04 or 0.05% fat, as measured by the ether extraction method. During separation, solid matter, known as *separator slime*, which consists of any dirt that may have been in the milk and some of the cells and bacteria, collects along the inside walls of the separator drum.

Properties of Cream

The consumer often judges the quality of cream by its appearance. If it is heavy or thick, it is considered to be of high fat

content and good quality; if thin, the reverse is assumed to be true. In reality, different lots of cream of the same fat content may vary greatly in their viscosity, but in general, an increase in fat content also increases the viscosity of the cream. Creameries usually control the processing of cream in order to obtain a product with considerable viscosity. If the cream is held a day

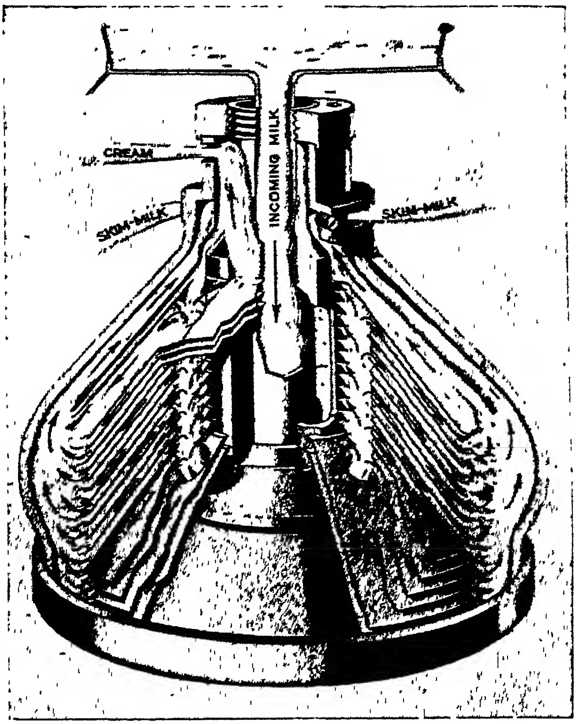


FIG. 29. *Diagrammatic View of Separator Bowl in Operation (Courtesy of The DeLaval Separator Co.)*

or so at a low temperature, about 40°F., it undergoes an increase in viscosity. Sometimes the cream is homogenized, since this increases its viscosity considerably. Pasteurized cream does not thicken with age as much as raw cream does and homogenized cream undergoes practically no increase in viscosity upon aging.

The *viscosity* of cream may be increased by a controlled heat treatment. This method, which is used to some extent, consists of heating the cream to about 87°F. for twenty minutes and then

cooling it slowly, over a period of twenty minutes to two hours, to a temperature of 70°F. and then rapidly to 40°F.[152] The addition to cream of dry milk solids or other materials in order to thicken it is an adulteration which happens but rarely.

The *cream line* or depth of the cream layer in bottled milk is of considerable commercial importance since the consumer often considers a deep cream layer indicative of rich milk. As a result, the attempt is made to produce as deep a cream line as possible for a given fat content of the milk. Agitation of milk while it is cold or processing and pasteurization at a high temperature causes a lowering of the cream line. Milk that is marketed in glass bottles therefore is not heated above 145°F. during pasteurization, or above 163°F. if high-temperature short-time pasteurization is used. Milk distributed in paper bottles does not show the cream line and its distributors may at times heat the milk somewhat higher during processing.

The thick layer of cream often found on the top of a bottle of milk or cream is called the *cream plug*. It is caused by the rise of large fat globules and usually contains from 60 to 80% of fat.

When cream is added to coffee or some other hot drinks, the cream sometimes coagulates with the formation of small, feathery flakes which float on the surface of the liquid. This is known as *feathering* and happens rather often if homogenized or very thick cream is used. If the coffee is made with hard water or the cream is slightly sour, the tendency for the cream to feather is increased.[153]

Whipping Cream

Whipping cream should contain not less than 30% fat. A fat content over 38% is not economical since the stiffness of the whipped cream is not increased if the fat content is over this amount. Whipped cream thickens because its fat globules form a continuous structure or bridgework which maintains a stable foam when air is forced into the cream.

For best results, both the bowl and the cream to be whipped should be at a temperature below 50°F. Only small amounts should be whipped at one time; successive whippings are better if large amounts are to be prepared. Cream that has been aged

whips better than it would otherwise and the addition of dry skim milk or calcium saccharate also improves its whipping ability. Calcium saccharate, a compound of lime and sugar, is known as *Viscogen* and at one time was used as an adulterant in cream. Sugar should not be added until the cream is whipped. The type of whipper used is an important factor in preparing whipped cream. One in which the blades revolve at the bottom of the bowl is more efficient than one of the egg-beater type, especially if only a small amount of cream is to be whipped.

A kind of whipped cream known as *aerated cream* is prepared by placing cream in a container with carbon dioxide or nitrous oxide gas under high pressure. When the pressure is released the product expelled resembles whipped cream. The amount obtained may be six to eight times that of the original volume of the cream.[154] The product is used by fountains and restaurants but in some localities it is not popular since the fluffy product is not similar to normally whipped cream. The use of nitrous oxide apparently is not deleterious to health.

Frozen Cream

Large amounts of frozen cream are stored for use by bakers and for the manufacture of ice cream. A storage temperature of 0°F. or lower is used. It is estimated that in normal times over one million gallons of frozen cream are available per year.

Before freezing, it is essential that the cream first be pasteurized or heated sufficiently to destroy the lipase that may be present. If this is not done the cream may become rancid during storage.

Canned Sterilized Cream

Owing to its high fat content, attempts to prepare a canned, sterilized cream have, until recently, been unsuccessful. By avoiding the procedures used to can evaporated milk and employing new techniques, it has been possible to prepare a sterilized cream which can be canned or bottled, and which will maintain its flavor and body for at least 2 years.[155]

Cream, of 18% or 30% fat content is used. Its acidity must be low, preferable not over 0.14 to 0.15%, expressed as lactic

acid. In order to prevent coagulation during sterilization, from 0.10 to 0.3% of sodium alginate, a gelatinous gum obtained from seaweed, is added. Sterilization is accomplished by adding steam under high pressure directly to the cream, which is heated in this manner to 260° to 280°F. for about 4 minutes. The cream is then homogenized at not over 2000 pounds pressure, followed by a second homogenization at about 500 pounds pressure. By carefully controlling the pressures, the desired viscosity of the cream is obtained.

After homogenization, the cream is cooled and held in sterile tanks from which it enters the bottle fillers. The cream is put up in bottles rather than cans, the bottles being sterilized with steam at 275°F. Bottling and capping is done in a room equipped with ultra-violet lamps to protect the product against air-borne contamination. The air in the bottling room is washed and filtered before it enters the room. It will be noted that the product is sterilized before being placed in sterile containers, in contrast to the method of making canned, evaporated milk, which is sterilized after being placed in the can.

Skim Milk

Skim milk is that portion of milk which remains after the cream has been removed, in whole or in part. The average composition of skim milk, as coming from a cream separator, is given in Table 13.

Until quite recently, skim milk had been considered an unworthy foodstuff for human beings, although large amounts of it are used for animal feed. Skim milk contains all of the nutriments of milk with the exception of the fat and the vitamins associated with the fat. When these deficiencies are supplied from other sources, skim milk is a wholesome food for human beings. It is used in the manufacture of some varieties of cheese, especially cottage cheese. Casein and milk sugar are prepared from skim milk and vast amounts of it are manufactured into dry skim milk. Much skim milk is condensed for use by bakers, confectioners and for the preparation of ice cream.

Condensed skim milk is made by evaporation of skim milk to about one-third of its original volume. Its composition is approximately as given in Table 13.

TABLE 13

Composition of Skim Milk and Condensed Skim Milk

	Water %	Protein %	Fat %	Lactose %	Ash %
Skim Milk	90.40	3.68	0.12	5.00	0.80
Condensed Skim Milk ..	70.32	11.83	0.37	15.10	2.38

A concentrated sour skim milk is used for animal and poultry feed. It is acidified by the addition of a culture of lactic acid-forming bacteria. As much as 6% lactic acid may be present.

Buttermilk

Genuine buttermilk is the liquid which remains after the fat is removed from milk or cream by the process of churning butter. If the butter is made from sweet cream or milk, the buttermilk does not differ materially from ordinary skim milk. If the milk or cream churned was sour or fermented, then lactic acid and somewhat less milk sugar is present than is found in sweet cream buttermilk. The preparation of cultured buttermilk is described in Chapter 10.

Except for a much lower fat and vitamin A content, genuine buttermilk has about the same composition and nutritive value as milk. When milk or cream is churned a great part of the phospholipids associated with the fat globules are retained by the buttermilk, thereby adding to its value as a phosphorus-bearing food. Buttermilk is easily coagulated in the stomach and the small curd formed facilities its digestion. The composition of buttermilk is given in Table 14.

TABLE 14

Average Composition of Buttermilk

Source	Water %	Protein %	Fat %	Lactose %	Ash %	Lactic Acid %
Sweet Cream	90.83	3.45	0.55	4.40	0.73	0.04
Sour Cream	91.30	3.40	0.65	3.40	0.65	0.60

A great amount of buttermilk is dried for use in bakery goods, pancake flour and animal feed. In 1945, about 49 million pounds of dried buttermilk were manufactured. Its composition is given in Table 18.

Whey

Whey is the product which remains after the removal of most of the casein and fat from milk. It is a by-product in the manufacture of cheese and casein. The greater part of the albumin, the lactose and the mineral matter of the milk remains in the whey. Cheese whey is an important source of lactose.

Large quantities of whey are condensed or dried for use as animal feed. Its high content of both lactose and riboflavin make it a valuable component of poultry feed. Some kinds of cheese, such as Primost and Ricotta are made from whey. Dried whey is used as an ingredient in certain types of cheese spreads and in some canned soups. In 1945, over 134 million pounds of whey were dried. The composition of some whey products are given in Table 15.

TABLE 15

Average Composition of Whey Products

Product	Water %	Protein %	Fat %	Lactose %	Lactic Acid %	Ash %
Cheese Whey	93.0	0.9	0.2	4.8	0.6	0.5
Condensed Whey ..	55.5	8.0	1.5	28.0	1.5	5.5
Dried Whey	6.0	12.2	2.7	65.8	2.9	10.4

Whey Butter

In cheese factories, where a large amount of whey is available, it is passed through a cream separator in order to recover the fat. The whey cream is churned and made into a very acceptable grade of butter. Whey butter, as it is called, is not distinguishable from butter made from ordinary cream. More than ten billion pounds of cheese whey were produced in 1942, from which about forty million pounds of butter were manufactured.

HOMOGENIZED MILK; SOFT CURD MILK; FROZEN MILK; CHOCOLATE MILK; EVAPORATED MILK; CONDENSED MILK

Homogenized Milk

Homogenized milk is defined by the United States Health Service Milk Code as "milk which has been treated in such a manner as to insure the break-up of the fat globules to such an extent that after 48 hours storage no visible cream separation occurs on the milk and the fat percentage of the top 100 milliliters of milk in a quart bottle, or proportionate volumes in containers of other sizes, does not differ by more than 10% of itself from the fat percentage of the remaining milk as determined after thorough mixing." [138, 156]

Milk is homogenized by pumping it under high pressure through the very small opening between a valve and its seat or between the narrow spaces of a series of discs pressed against each other by means of a heavy spiral. The openings through which the milk is forced may be adjusted to within 0.001 inch. Two-stage homogenizers have two separate valves through which the milk is pumped. The pressure on the second stage usually is less than that used on the first stage.

The fat globules in milk become subdivided when they are forced through a very small aperture and they practically *explode* as they reach the other side where the pressure is suddenly released. The greater the pressure used, the smaller will be the size of the fat globules. The ability of the globules to combine or coalesce is practically destroyed owing to the presence of a film of protein which forms around them. No appreciable cream layer is formed on homogenized milk since the small size of the fat globules and their inability to coalesce greatly decrease their ability to rise to the surface. A pressure of 2500 to 3000 pounds per

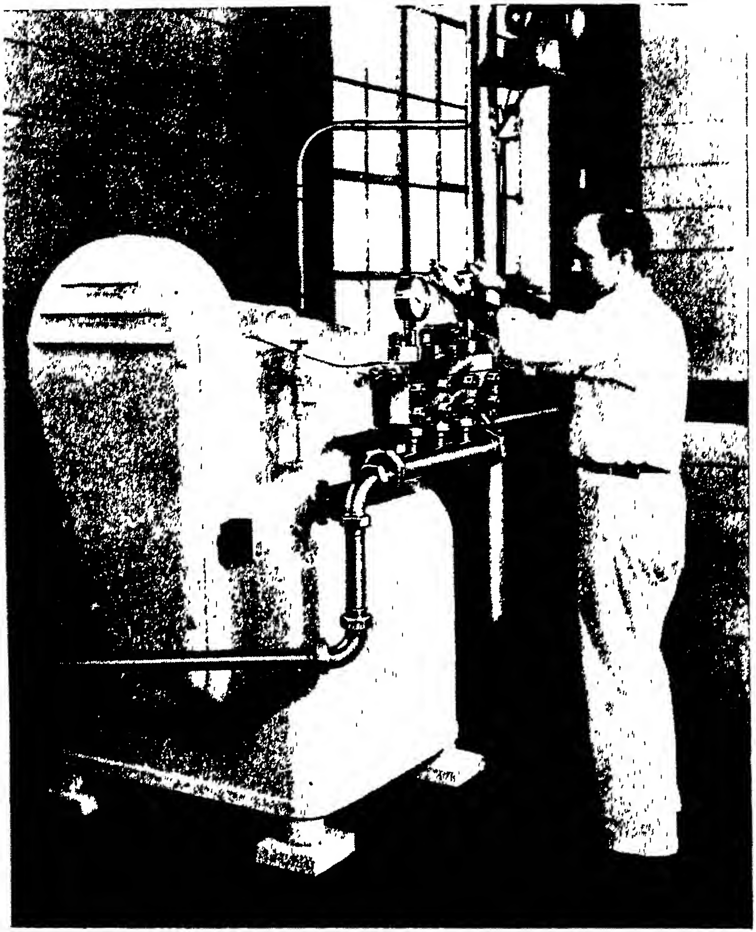


FIG. 30. *Homogenizer in Operation*
(Courtesy of Creamery Package Mfg. Co.)

square inch generally is used for homogenization but 1500 pounds often is sufficient to prevent cream formation on milk.

The greatly increased number of fat globules and the much greater surface area they possess make homogenized milk very susceptible to the action of lipase, with consequent development of rancidity (see Chapter 5). To prevent this, homogenized milk must be made from pasteurized milk or the milk must be pasteurized after homogenization. A temperature of 148° to 150°F.

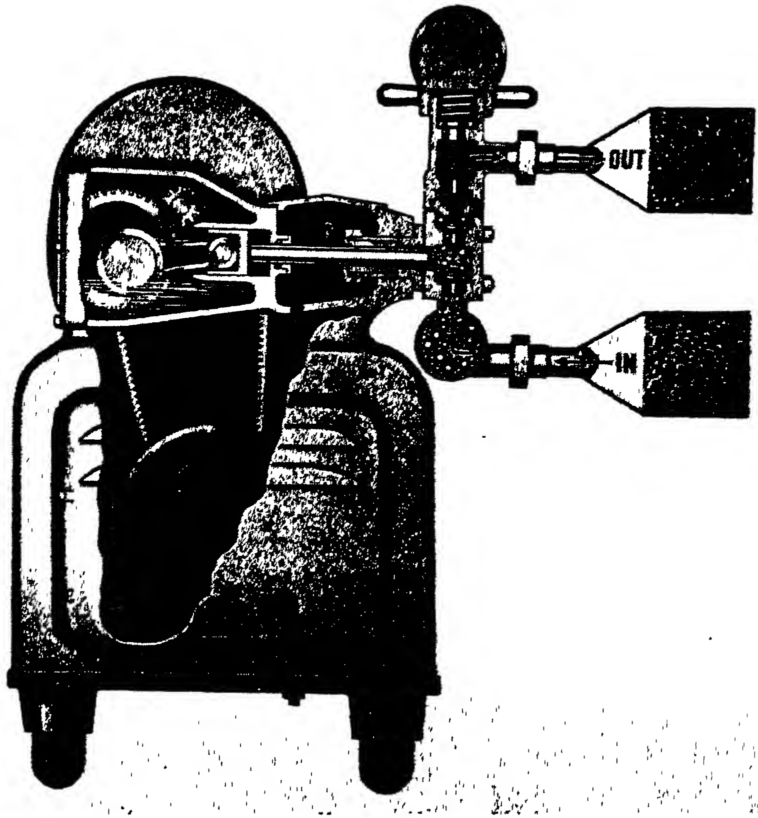


FIG. 31. *Diagrammatic Illustration of Homogenizer in Operation*
Note comparative size of fat globules upon entering and leaving the machine.
(Courtesy of Creamery Package Mfg. Co.)

for ½ hour may be used for pasteurization since in the case of homogenized milk there is no concern about the cream line. Since the consumer usually judges the richness of milk by the depth of its cream layer, the lack of a cream line on homogenized milk is one reason why, at first, it was not widely used in this country. Advertising and the use of paper containers have served to overcome this objection.

Although homogenization will prevent the formation of large individual fat globules, it does not prevent the small globules formed in the process from clumping together or adhering to each other. This clumping action increases the viscosity of the

product, especially in the case of homogenized cream, and homogenization is used to give a desirable body to cream and ice cream. It is also employed in the manufacture of cream cheese and to incorporate vitamin concentrates into fortified milk. Evaporated milk is homogenized in order to delay the fat from rising or separating during storage. A homogenized mixture of milk and cream containing about twelve percent of fat is known as "half and half."

Normal Milk | Poorly Homogenized | Homogenized

FIG. 32. *Fat Globules in Milk and Homogenized Milk*

Magnification about 1000 times. Each space between the small vertical lines represents two microns (one micron is about 1/25,000 inch). *(Courtesy of Creamery Package Mfg. Co.)*

Homogenization alters the physical condition of the protein in milk and makes it more easily coagulated by heat or acid. This change, together with that produced by the subdivision of the fat globules gives homogenized milk the characteristics of a soft curd milk.

Sediment in Homogenized Milk

It is not unusual to find a layer of sediment on the bottom of a bottle of homogenized milk. This sediment consists of a mixture of the leucocytes and other cells normally present and any foreign material which may have been in the milk before homogenization. Ordinarily these substances, especially the leucocytes, remain suspended in the milk or rise with the cream, but since homogenized milk does not form a cream layer, the cells and other material sink to the bottom and become very noticeable. Clarification, especially after the milk is homogenized, is the best

method to remove the sediment. Filtration is not efficient for this purpose.[157]

Soft Curd Milk

The observation that milk from different cows may vary according to the kind of curd it will form has been made the subject

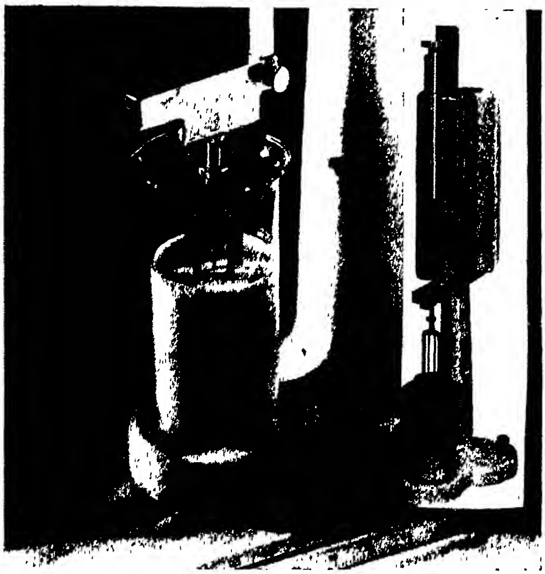


FIG. 33. *Close-up of Curd Tension Knife in Operation (Courtesy of Golden State Co., Ltd.)*

Insert: Curd Tension Meter. *(Courtesy of Submarine Signal Co.)*

of considerable research. It long has been known that heated milk will produce a soft coagulum while milk that is high in acid will form a firm curd with rennet. A somewhat similar reaction occurs with such milks during digestion in the stomach.

A number of ways have been devised to measure the hardness or tension of the curd formed by milk. In one commonly used method, the milk is coagulated by the addition of a mixture of

dilute acid and pepsin which simulates the gastric juice. Before it is coagulated, a multi-bladed knife is placed in the milk and after coagulation has taken place, the tension, measured in grams, is determined by the force needed to pull the knife through the curd. This force is known as the curd tension of the milk and is a measure of its hardness.[158]

The curd tension of most cow's milk ranges from fifty to ninety grams. Soft curd milk has a tension of thirty grams or less and milk with a curd tension over sixty grams is classed as hard curd milk. Cows that give natural soft curd milk are relatively few in number. As a rule, Holstein and Ayrshire cows give soft curd milk more commonly than do Guernsey and Jersey cows.[158]

The principal chemical difference between natural soft curd and hard curd milks has been found to lie in their casein content. Hard curd milk contains more casein and if this difference is equalized by the addition of water, the curd tension of the milk is reduced. Since natural soft curd milk is of relatively low casein content, its nutritive value is less than that of ordinary milk. A number of authorities believe that if soft curd milk is desired for feeding purposes, it should be obtained by processing milk of normal composition. Among the simplest procedures for this purpose are heating or boiling the milk, adding dilute acid, citrate, gelatin, cereal or diluting with water. Infants with weak digestive systems probably are benefited by the use of milk formulas which result in the formation of a soft, loose curd in the stomach. Such a coagulum presents a large surface to the digestive juice, in contrast to the hard and relatively impenetrable curd formed by hard curd milk.

The ability of children to digest milk varies greatly with their age and physical condition. The alteration of the curd character of milk for infant feeding is a practice of long standing. Cow's milk even if boiled, is more difficult to digest than breast milk, but acidified milk, buttermilk and diluted evaporated milk are practically as easily digested as breast milk. These milks have a curd tension of zero. Pasteurization reduces the curd tension of cow's milk about twenty percent and if the milk also is homogenized, the reduction amounts to about sixty percent.

Sonic vibration sometimes is used to produce a soft curd milk; the product is very similar to ordinary homogenized milk. The

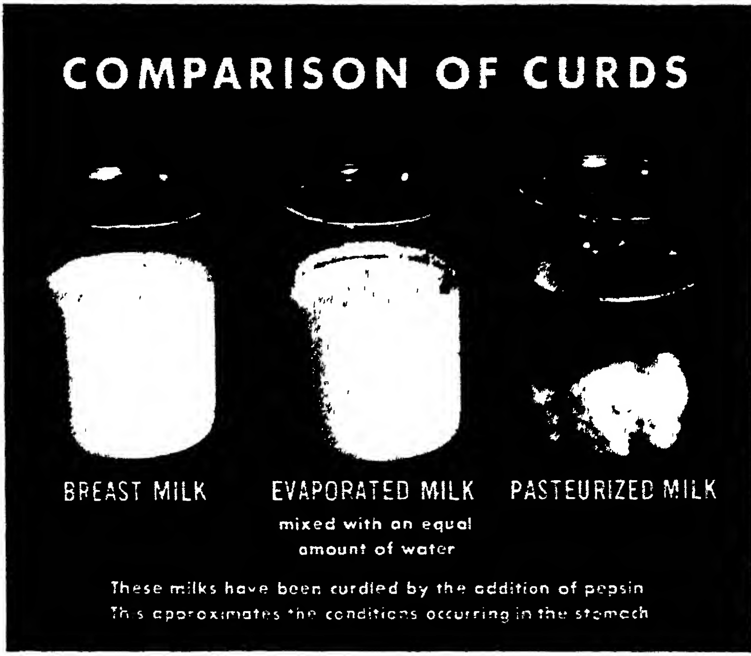


FIG. 34. *Comparison of Curds*
(Courtesy of Evaporated Milk Association.)

process consists of passing a thin film of milk over a stainless steel diaphragm, about 2 feet in diameter, which is vibrated electromagnetically at a frequency of 360 vibrations per second.[159] The mechanical agitation changes the physical character of the milk so that the fat globules are reduced in size and the curd tension is lowered (Fig. 35).

The partial digestion of the milk proteins by the action of enzymes and the removal of some of the calcium from the milk by an exchange system similar to that used to soften water are other methods that have been used to produce soft curd milk.[160, 161, 162]

Whether or not soft curd milk produced by mechanical means is better than that obtained by the use of heat or accepted formulas is an unsettled question. It has been claimed that the variability in the production of soft curd milk and the increased effort needed to make it, together with the lack of superior results obtained with it compared to those given by boiled, evaporated or formula

milk, does not warrant the special production of soft curd milk for infant feeding.[163] A detailed study of the digestive characteristics of various types of milk compared with human milk showed that curd tension measurement is of little value in predicting the digestibility and curd character of a milk.[146, 199]

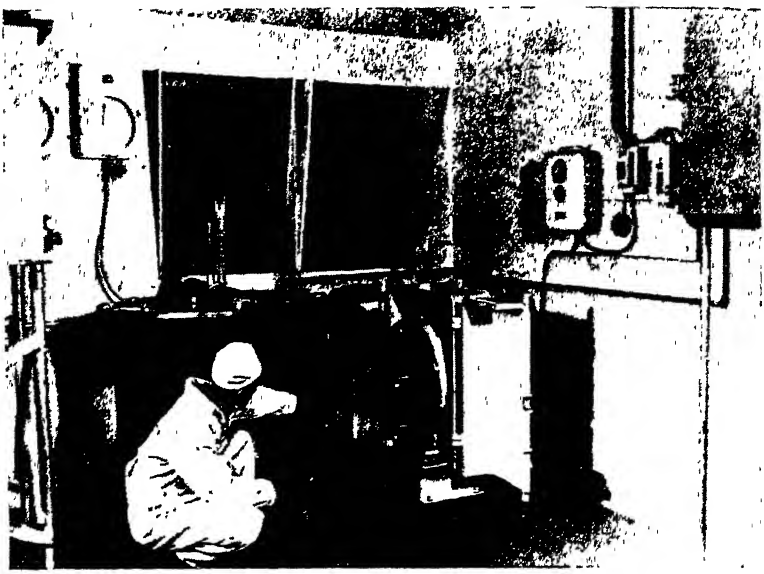


FIG. 35. *Sonic Oscillator in a Dairy*

Showing pasteurizing vat and open view of sonic oscillator. The oscillator is enclosed in a sound box to minimize audible sound during operation. *(Courtesy of Submarine Signal Co.)*

Frozen Whole Milk

During World War II large amounts of fresh, pasteurized milk were frozen for shipment to overseas bases and hospitals. The milk was contained in waxed paper cartons, twelve of which were placed into a fiberboard container. This container was placed into a freezing unit where the milk was frozen rapidly at a temperature of about –20°F. During shipment and storage, the frozen milk was held at a temperature of 10° to 15°F. Twenty-four hours before using, the frozen milk was placed in an ordinary refrigerator, in which the temperature is about 36° to 40°F. Here

the milk thawed slowly. Milk 3 months old, treated in this manner, was found to have a natural appearance, good flavor and low bacterial content.

Chocolate Milk

Chocolate milk or chocolate flavored milk is an important dairy product and is used by many people who otherwise would not drink milk. When it contains less than the legal amount of milk fat, the product is given some fanciful name, such as *chocolate dairy drink*. In general, chocolate milk contains about one percent of cocoa and from five to seven percent of sugar. Usually a stabilizer, such as vegetable gum, starch or sodium alginate, is added to prevent the cocoa from settling out.

Some authorities on the nutrition of children have criticized the use of chocolate milk on account of its cocoa and sugar content. It has been shown that the indiscriminate use of chocolate-flavored foods may lower the retention of dietary calcium and phosphorus, especially if the diet is already low in calcium.[164]

Evaporated Milk

Evaporated milk, sometimes called unsweetened condensed milk, is whole milk from which about 60% of the water has been removed by evaporation. The legal definition of evaporated milk is "the product resulting from the evaporation of a considerable portion of the water from milk, or from milk with adjustment, if necessary, of the ratio of fat to non-fat-solids by the addition or by the subtraction of cream. It contains not less than 7.90% of milk fat and not less than 25.9% of total milk solids." One pound of evaporated milk is the equivalent of about 2.25 pounds of liquid whole milk. The calorific value averages about 44 calories per ounce.

Evaporated milk is the most widely used form of concentrated milk. Probably no other foodstuff is canned in such a vast amount. In 1945 the production of evaporated milk in the United States was more than 3776 million pounds, in 1946, 3082 million pounds.

The manufacture of evaporated milk requires the use of milk of good quality. The raw milk is graded carefully by chemical and bacteriological examination and then is weighed and passed

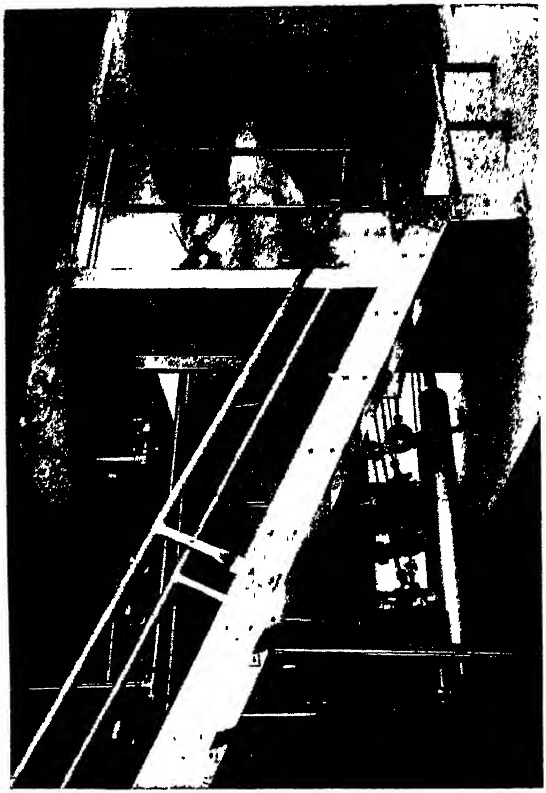


FIG. 36. *Vacuum Pan Used in the Manufacture of Evaporated Milk (Courtesy of Mojonnier Bros. Co.)*

through a filter to remove any dirt or foreign substances that might be present.

The milk is heated to a temperature of 190° to 210°F., the exact temperature and time used depending upon the procedures used in the plant. This step is called *forewarming* and is important since it prevents the milk from becoming coagulated when it is sterilized at a high temperature after the evaporation process. The hot, forewarmed milk is drawn into a vacuum pan where it is condensed to the required composition. The vacuum maintained is such that the milk boils at a temperature between 130° and 135°F. About 60% of the water is removed. After evaporation, the milk is homogenized in order to prevent fat separation in the finished product. The homogenized milk is cooled and

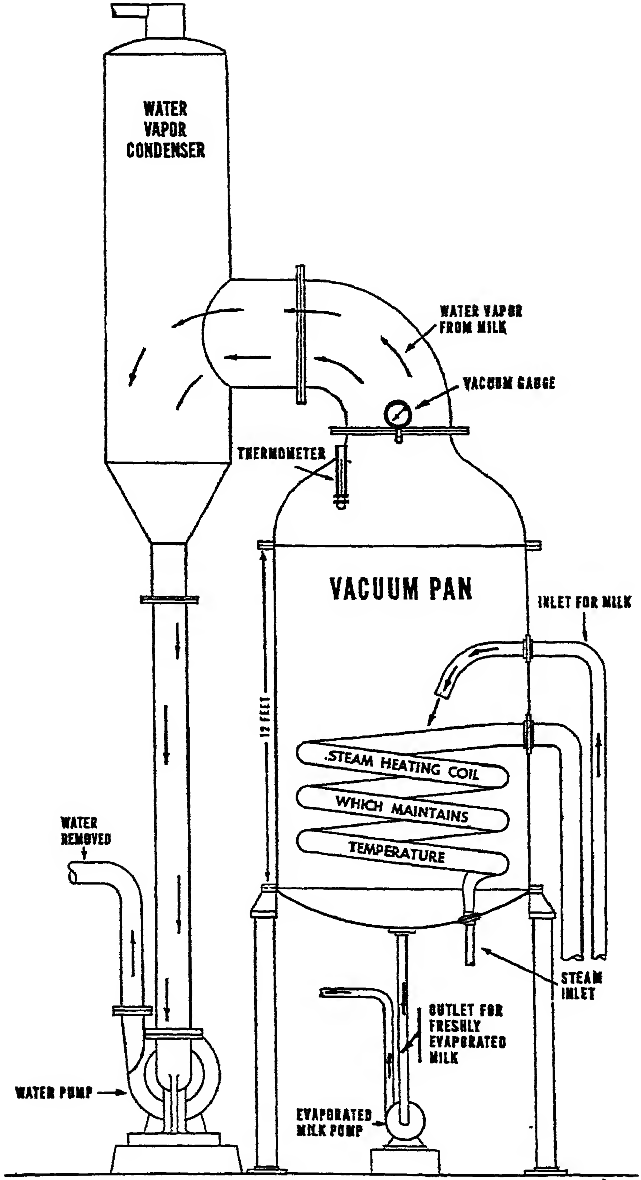


FIG. 37. *Diagrammatic View of a Vacuum Pan Used for the Manufacture of Evaporated Milk*
(Courtesy of Evaporated Milk Association.)

standardized if necessary in order to insure that it contains the proper fat and total solids content.

If the vitamin D potency of the evaporated milk is to be increased, it usually is done by adding a vitamin D concentrate to the milk before it is homogenized. Irradiation with ultra-violet light to increase the vitamin D content is discussed in Chapter 3.

Experience has shown that some lots of evaporated milk may coagulate during sterilization, even though they had been preheated. In order to prevent this, the milk is tested by sterilizing a small amount in cans placed in a pilot sterilizer and giving it the same heat treatment as used for sterilization. To some of the cans there is added a small, measured amount of an inorganic salt. Disodium hydrogen phosphate often is used, but sodium citrate and calcium chloride are also employed. Only a fraction of a pound of one of these *stabilizer salts* is added per 1000 pounds of milk. The amount used actually lies within the variation of the salts which occur naturally in milk. If the pilot sterilization of the can of untreated milk gave satisfactory results, the bulk of the milk is processed without further treatment. If some of the cans contained coagulated milk, the smallest amount of stabilizer needed to prevent coagulation is determined and added to the bulk of milk to be sterilized.

After the evaporated milk has passed all tests, it goes to the can-filling machine. Here it is forced into the can through a small hole in the top cover. The weight of milk can be adjusted to within 1/25th of an ounce. Usually, *baby size* cans holding 6 ounces and *tall* cans that hold 14.5 ounces are filled, but a *confectioner's* size of 8 pounds is also used. The filling machine solders automatically the small hole through which the milk enters. The cans pass to the can-tester, where the cans travel fully submerged, through a tank of hot water. A defective can is detected by the presence of air bubbles and is removed. Some plants use a vacuum device to test the cans. A vacuum cup picks up the sealed can which by means of a conveyor belt is carried to the sterilizer. Imperfectly sealed cans drop from the vacuum cup and are not carried to the sterilizer.

Evaporated milk is sterilized either by a batch process or in a continuous sterilizer, processes very similar to those used in the canning of fruits and vegetables. In the batch process, the cans are placed in a container or metal basket which revolves in

a steam-tight container, similar to a large pressure cooker. The agitation insures uniform heating. The milk is heated gradually, by means of steam, to 235°–245°F. at the rate of about 5°F. per minute. It is held at the maximum temperature for about 15 minutes. The sterilizer then is filled with cold water and the cans are cooled quickly to about 90°F.

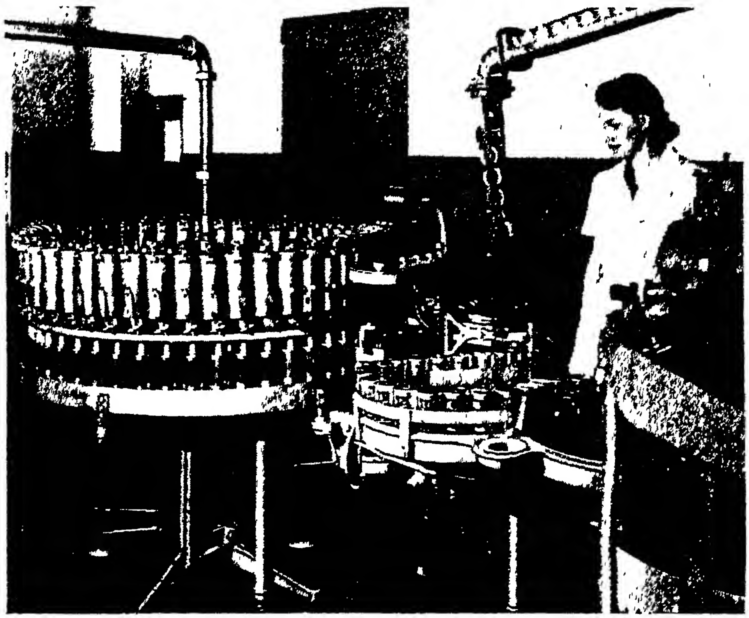


FIG. 38. *Can Filling and Sealing Machine*

Empty cans enter the machine over the conveyer at the operator's right. They are filled by the time they have traveled around the circle. Each can is sealed automatically with a drop of solder before it leaves the machine. Note roll of solder near the sealing unit. *(Courtesy of Evaporated Milk Association.)*

Often, evaporated milk is sterilized by the continuous process. The cans first enter a preheater wherein they pass along a spiral track at the rate of about 100 cans per minute. Here the temperature of the milk is raised gradually to 198°–210°F. in about 15 minutes. The heated milk expands and slightly bulges the ends of the cans, unless they are leaky or not air-tight. As they leave the preheater, the bulged cans travel over a pair of rails so spaced that the bulged cans pass over them but any cans that are not bulged fall through and so are automatically rejected.

From the preheater, the cans enter the sterilizer, where they are heated by steam under pressure, at a temperature of about 243°F. About 16 minutes is required for sterilization, during which time the cans travel along a spiral track through the sterilizer. The agitation prevents the milk from burning or adhering to the sides of the can. The travel along the spiral track corresponds to the revolving basket used in the batch sterilizer. After they are sterilized, the cans of milk enter a cooling unit wherein

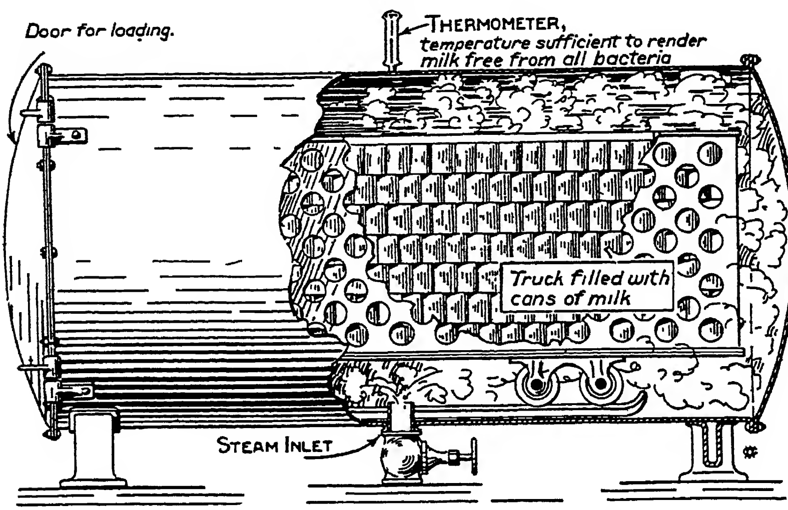


FIG. 39. *Diagrammatic View of a Batch Sterilizer*

The truck is filled with sealed cans of evaporated milk and rolled through the door into the sterilizer. After the door is closed, steam is admitted to heat the milk to sterilizing temperature. *(Courtesy of Evaporated Milk Association.)*

their temperature is lowered by means of cold water to about 85°–90°F. in about 11 minutes. Within the cooling unit an air pressure of about 10 pounds per square inch is maintained in order to prevent mechanical strains from rupturing the cans as they cool. During cooling, the pressure within the cans is decreased and the bulged ends contract to their normal position. If a can is leaky, the air pressure within the cooler keeps the ends bulged. This difference in size again is made use of to reject any defective can as it passes over a track when they leave the cooler. The width of the track is such that normal cans drop through, but one with bulged ends will span the track and continue to roll on and so be separated from the other cans.

FIG. 40. *Continuous Sterilizer*

Two of the three units comprising the sterilizer are seen. Note the continuous flow of cans into the sterilizing unit. *(Courtesy of Evaporated Milk Association.)*

During sterilization, the milk may acquire a jelly-like consistency, known as *liver*. The cans with the sterilized milk made by the batch process, if jelled, are put in a mechanical shaking device which by vigorous shaking removes the *liver* and gives the evaporated milk a smooth texture. The agitation given the cans in the continuous sterilizer is sufficient to prevent the formation of *liver*. After shaking, the cans are labeled and conveyed to packing and storage rooms.

The average chemical composition of evaporated milk is given in Table 16.

TABLE 16

Average Composition of Evaporated Milk

Fat %	Protein %	Lactose %	Ash %	Water %
7.93	6.88	9.85	1.48	73.86

The calcium content is about 0.27%; magnesium 0.025%; phosphorus 0.20% and iron about 0.0004%.

The heat treatment and the high temperature used for sterilization give the evaporated milk a darker color than normal milk has. The increase in color is not due to the increased concentration of the milk solids.

Sterilized, canned, evaporated milk will keep indefinitely. In time the fat will rise, either as a thick layer or in globules. The homogenization and the heavy body of the milk will delay the rising of the fat but does not prevent it. A decided change in color takes place as the milk ages over a period of months; the original creamy or brownish color gradually acquires a yellowish to greenish hue. Old evaporated milk loses much of its original viscosity and usually has a thin body.

Nutritive Value

Although evaporated milk has undergone changes in its physical and chemical characteristics, it has high nutritive value.[165] The curd formed in the stomach is soft and spongy, similar to that formed by breast milk, in contrast to the hard, compact curd formed by most raw or pasteurized milk. The fat globules are finely divided by homogenization and therefore are easily digested. The changes produced in the protein by the heat treatment make it assimilable by infants who in many cases cannot tolerate ordinary milk.

Vitamin Content of Evaporated Milk

Evaporated milk is an excellent source of vitamin A. The heat treatment given the milk destroys about one-fifth of its thiamine content. There is little, if any, loss of riboflavin since this vitamin is not affected by the heat treatment. Evaporated milk is a poor source of ascorbic acid and usually contains less than one-half of the vitamin originally present in the milk. Recent work has shown that the fortification of evaporated milk with ascorbic acid is practical.[166] Since evaporated milk is used so extensively as a food for infants and children fortification with ascorbic acid may be advantageous. However, vitamin C fortified evaporated milk is not as yet commercially obtainable. Infants' formula milk

should be supplemented with ascorbic acid from sources such as citrus fruit juices. Vitamin values for evaporated milk are given in Table 5.

Because milk normally contains but a small and variable amount of vitamin D, many manufacturers fortify evaporated milk with vitamin D. Enough vitamin D is added to each can to yield a milk with 400 units of the vitamin per quart when the evaporated milk is diluted with an equal amount of water.

Filled Milk

Filled milk is evaporated skim milk to which coconut fat or some other edible vegetable fat has been added to replace the milk fat. The sale of filled milks is prohibited in interstate commerce as these products are considered to be of inferior nutritive value and the uninformed consumer may purchase them under the impression that they are equivalent to evaporated milk.

Evidence gathered from studies concerning the nutritional value of milk, milk fat, margarine and vegetable fats indicates that whole milk is superior to filled milk for very young animals and should be used for feeding infants but no advantage of one product over the other has been demonstrated for the adult.[107]

Sweetened Condensed Milk

The United States Department of Agriculture defines sweetened condensed milk as "the product resulting from the evaporation of a considerable portion of the water from milk to which sugar and or dextrose has been added. It contains not less than 28% of milk solids and not less than 8% of milk fat."

Evaporated milk is preserved by heat treatment in the can, but sweetened condensed milk is a concentrated milk product preserved with sugar. It first was made on a commercial scale about 1858 in New York by Gail Borden. When the method for evaporating and sterilizing milk was perfected, the use of sugar as a preservative decreased.

Milk for the manufacture of sweetened condensed milk, after passing chemical and bacteriological tests for quality, is heated to a temperature of 170°–185°F. and mixed with sugar. Either cane or beet sugar is used as well as some dextrose or corn sugar.

The amount of sugar added is about 16% of the weight of the fresh milk, or enough to give 40 to 45% in the finished product. This amount of sugar does not form a saturated solution and the sugar will not crystallize from the condensed milk. However the volume of water left in the concentrated product is not sufficient to hold all of the lactose in solution and this sugar does separate from sweetened condensed milk.

Considerable care is taken in the heating and cooling procedures since they have a great influence upon the body or viscosity of the finished product as well as upon the degree of lactose separation. The milk is cooled rapidly to between 80° and 86°F. and held there for 15 or 20 minutes. Often the milk is *seeded* at this time. A small amount of a previous batch of sweetened condensed milk, or a few ounces of powdered lactose, or even some dry skim milk powder is added under vigorous agitation. The material so added forms areas or nuclei upon which a large number of small lactose crystals will form. The larger the number of crystals that can be formed, the smaller will be the size of each individual crystal. The small crystals do not rapidly settle out of the finished product, and being small, are not very noticeable to the taste. Fairly large crystals give the milk a gritty body and the product is said to be *sandy*.

The average composition of sweetened condensed milk is given in Table 17.

TABLE 17

Average Composition of Sweetened Condensed Milk Products

Product	Water %	Protein %	Fat %	Lactose %	Sucrose %	Ash %
Whole Milk..	27.85	8.15	8.45	12.90	40.80	1.85
Skim Milk...	29.00	9.10	0.95	18.00	41.00	1.95

There is some loss of thiamin and ascorbic acid during the manufacture of sweetened condensed milk, but no significant loss of riboflavin occurs.

Large amounts of sweetened condensed milk are used by the baking, ice cream and confectionery industries, and it is used widely as an infant food. About 220 million pounds were made in 1945.

Sweetened Condensed Skim Milk

Except for its lower fat content, sweetened condensed skim milk is very similar in its properties and uses to sweetened condensed milk. Its approximate composition is given in Table 17. About 512 million pounds were made in 1945, most of which was sold in bulk to bakers and confectioners.

Bacteriology of Evaporated and Condensed Milk

It is generally assumed, that all bacteria originally present will be destroyed during the manufacture of evaporated milk. However, there are cases on record in which bacterial activity in canned evaporated milk has been observed.[23]

Generally, the bacteria in evaporated milk cause coagulation of the product, but gas formation and off-flavor, especially bitterness, occur also. The thickening of the milk during sterilization should not be attributed to bacterial activity. After the can is opened the contents should be treated with the same care given fresh milk.

Sweetened condensed milk is not a sterile product. Its high sugar content prevents the growth of bacteria and acts as a preservative. Molds, which form hard, colored bodies or *buttons* are sometimes found on the surface of the product. Occasionally, gas formation, usually caused by sugar-fermenting yeasts occurs. These conditions are not found in the canned product unless sufficient oxygen is present to permit growth of the organisms. This may be the case when the product is handled in bulk by bakers and other industrial users.

Chapter 14

DRY MILK; MALTED MILK

Dry Milk

Milk, skim milk and buttermilk as well as cream, whey and other liquid milk products may be dried by either a spray or drum drying process. The first mention of a dried milk product appears to have been made by Marco Polo, who wrote that the Mongols boiled milk, removed the cream and dried the remaining liquid in the sun. A patent was granted in England in 1855 for a method to dry milk by evaporation in an open pan and in 1862 a patent was issued in the United States for a process to dry milk by a spray method. These ventures were not practical and it was not until 1883 that the process for making malted milk provided the first commercially successful dry milk product.

Drum or Roller Drying

Drum or roller driers for the manufacture of dry milk are either of the open or atmospheric type or of the vacuum type. One or two steel drums or rollers, which may range from about four to ten feet in size, dip into a container which holds the milk to be dried or, on some machines, the trough formed by the contact of two rollers, acts as the milk container. The drums or rollers are heated by steam or hot water and depending upon the size of the unit, are capable of drying from about 1000 to 3000 pounds of milk per hour.

In vacuum drum dryers, the rollers are enclosed in a chamber from which the air is withdrawn, thus permitting the milk to be dried at a much lower temperature than that used for atmospheric drying.

As the drum or drums of the dryer revolve, a thin film of milk adheres to them and is dried by the time a complete revolution is made. This takes from 6 to 30 seconds, depending upon whether

FIG. 41. *An Installation of Two Roller Dryers*
(Courtesy of Buflovak Equipment Division of Blaw-Knox Co.)

or not the milk to be dried had been previously condensed by evaporation. The dried milk, usually in the form of a sheet or film, is removed from the drums by means of knives or scraper blades and falls into a hopper from which it is transferred to a receiving bin. Usually the product is ground to powder form.

The roller process is used mostly for drying skim milk, buttermilk and whey, especially if the product is to be used for animal feed. The high drying temperature used for the atmospheric process yields an insoluble product whereas a relatively soluble dry milk is obtained by vacuum drying.

Spray Drying

In the spray drying process a fine spray of milk is forced rapidly through a stream of hot air. This is done either by whirling the milk by centrifugal force from the edge of a rapidly revolving disc or by pumping it under considerable pressure through a spray nozzle. The dry milk particles fall to the bottom of the drying chamber while the heated air carries the water vapor away. Dry

milk made by a spray process is in the form of tiny spheres and usually is very soluble. Spray process units vary considerably in size and are more intricate and costly than the relatively simple roller dryers. The smaller spray driers have a capacity of about 3000 pounds of milk per hour but units that handle more than 10,000 pounds of milk per hour are also in use.

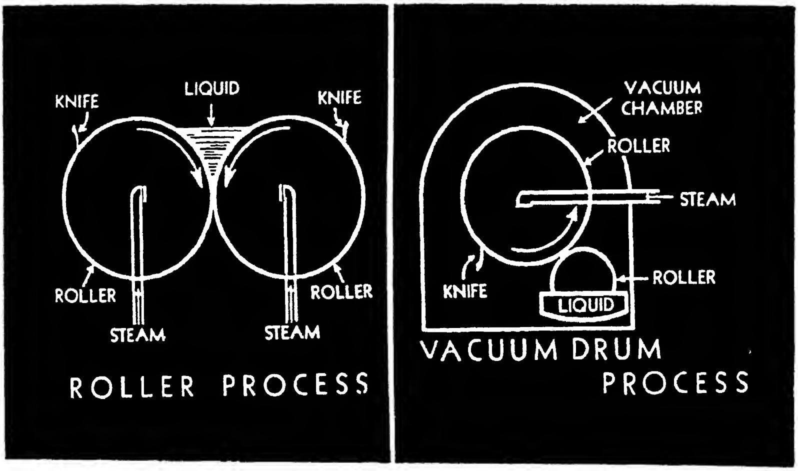


FIG. 42. *Diagrammatic View of Roller and Vacuum Drum Dryers (Courtesy of American Dry Milk Institute.)*

Dry Whole Milk

Large amounts of dry whole milk were manufactured for use of the armed forces during World War II. Owing to its high fat content, dry whole milk has relatively poor keeping properties and in order to prevent rapid deterioration, the product is packed in cans from which the air is removed and replaced by an inert gas, such as nitrogen or carbon dioxide.[168, 187] By mixing with water a very satisfactory milk is obtained, which often cannot be distinguished from ordinary milk by the consumer. Reconstituted milk, made in this manner, is finding increasing use, especially in tropical Latin-America.

Dry whole milk is used by bakers, confectioners and in the manufacture of milk chocolate. It is also packaged in small containers for sale in grocery stores. The composition of dry whole milk is given in Table 18.

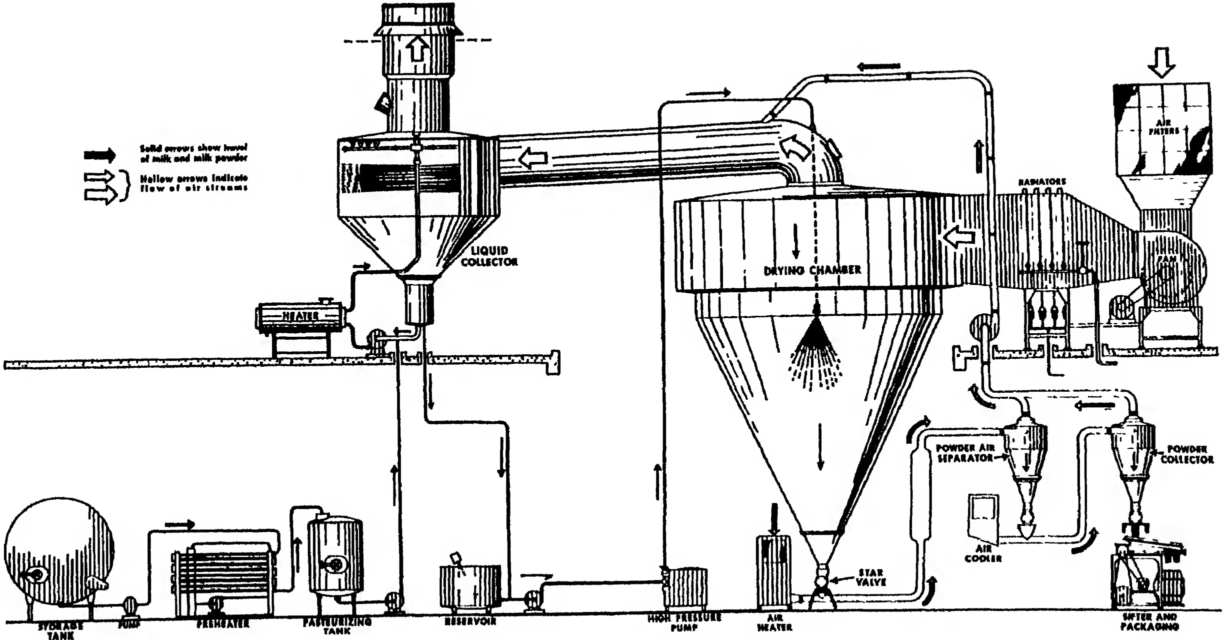


FIG. 43. *Diagrammatic View of Spray Process Milk Drying Plant*

Milk from the storage tank is pasteurized and then pumped to the heater and liquid collector where hot exhaust air from the drying chamber partially condenses the fluid. After the desired consistency is obtained the milk is pumped under high pressure to the atomizer in the drying chamber. Here the incoming hot air almost instantly dries the milk. It falls to the bottom of the dryer from which it is removed continuously to the sifter and packaging unit. *(Courtesy of Swenson Gray-Jensen Evaporator Co.)*

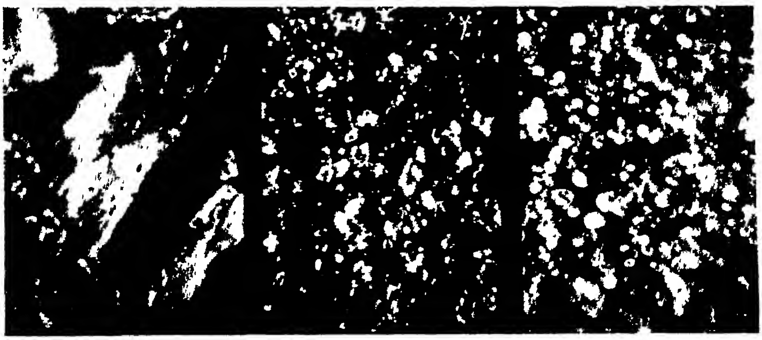
Fig. 44. *Drying Unit of a Large Spray Drier (Courtesy of Golden State Co., Ltd.)*

Dry Non-fat Milk Solids

Owing to the unfavorable reaction which many people have to the term *skim milk,* the dairy industry refers to dry skim milk as *dry non-fat milk solids.* This term is descriptive of the product and does not minimize its high nutritive value.

Vast amounts of dry non-fat milk solids are used by the baking

industry, not only in bread but also in cakes, crackers, doughnuts and pie fillings. The lactose of the milk is caramelized during baking and gives the bread crust a desirable, uniformly brown color. For the same reason, bread that contains milk solids yields a better colored toast than does plain bread. Owing to its ability to retain moisture, milk bread usually will remain fresh much longer than bread made without milk solids. Milk adds to the nutritive value of bread since it supplies mineral salts and proteins that are lacking in wheat flour. Up to 20% of the weight of flour used may be replaced by non-fat milk solids. Bakers generally use 6% or less. Owing to military and lend-lease demands, bread



Roller Vacuum Drum Spray

FIG. 45. *Appearance of Dry Milk Products Under Microscope (Courtesy of American Dry Milk Institute.)*

made during World War II usually contained about 3% of non-fat milk solids. When 6% of the weight of the flour is replaced by dry non-fat milk solids, the bread will contain about 50% more phosphorus, 16% more protein and about 300% more calcium than white bread made without milk solids.

Much dry non-fat milk solids is used in the manufacture of prepared pancake, waffle and biscuit mixtures. In some of these products, the shortening is a spray-dried mixture of vegetable fat and skim milk.

Dry non-fat milk solids are an important ingredient of ice cream mix and the powder sometimes is added directly to the freezer in order to increase the milk solids content of the ice cream without causing it to become *sandy*.*

* U. S. Patent 1,878,127 (1932).

Infant foods, cocoa and chocolate drinks, malted milk and other beverages often contain dry milk non-fat solids. Meat products, such as sausages and frankfurters contain non-fat milk solids since they aid in the retention of moisture and give a plump appearance to the product. Many cat and dog foods, as well as feeds for poultry, calves and other domestic animals contain non-fat milk solids, usually made from milk of inferior quality as well as from buttermilk and whey.

Some soap and cosmetic preparations contain dry milk solids and mixtures of starch and dry non-fat milk solids have been used as dusting and cosmetic powders.

The composition of dry milk products is given in Table 18.

TABLE 18

Average Composition of Dry Milk Products

Product	Water %	Protein %	Fat %	Lactose %	Ash %	Citric Acid %
Whole Milk Solids .	2.0	26.8	27.6	36.4	6.0	1.2
Non-fat Milk Solids	3.0	36.3	1.0	50.0	8.0	1.7
Cream Solids	0.56	11.23	70.85	14.88	2.48	...
						(Lactic Acid)
Buttermilk Solids ..	2.0	39.2	5.9	39.85	7.55	5.50

Nutritive Value of Dry Milk

The nutritive value of dry milk is essentially that of the milk before drying. Most investigators agree that, except for the ascorbic acid content, most of the vitamins present suffer little change during drying.[169] It was found that there is a loss during drying of less than 10% of the vitamin A originally present. During a 6 month storage period, no loss of vitamin A occurred in gas-filled containers held at room temperature. When stored in air-packed containers, the vitamin A content decreased about 6%. A loss of 10, 15, and 30% respectively occurred when the dry milk was stored under similar conditions at 100°F.[170] No loss, either during drying or storage, was detected in thiamine, riboflavine, niacin, calcium pantothenate, biotin, and pyridoxine.

The vitamin content of dry milk is given in Table 5.

FIG. 46.

Showing amount of dry whole milk (about 4.5 oz.) obtained from one quart of milk. *(Courtesy of Golden State Co., Ltd.)*

Bacteria in Dry Milk

As the milk is dried very rapidly and at a comparatively low temperature, many bacteria that may be present in the milk are not destroyed and spore-forming organisms especially may survive. Methods of drying which employ a holding or circulatory system for the hot milk may increase the bacterial content of the milk by supplying conditions that favor the growth of thermophilic organisms. If the milk is first preheated to a high temperature most of the bacteria present are destroyed. Because of the high temperatures used in the manufacture of roller-dried products, they usually have a lower bacteria content than the corresponding spray-dried products.

United States Government specifications for dry whole milk require that its bacterial content must not exceed 50,000 per gram of powder. The standards of the American Dry Milk Institute specify that when dry milk solids-not-fat are reconstituted by dissolving 10 grams of the sample in 100 milliliters of sterile water, the bacterial count per milliliter must not exceed 15,000 for the *Extra grade* powder or 50,000 for the *Standard grade.*[171]

Conditions during storage of dry milk are not favorable to

the survival of bacteria and there is a gradual decrease in their number with the passing of time.

Dry Cream

Cream may be dried by a spray process. It gives a light, cream-colored powder, usually somewhat flaky in appearance. Dry cream is used by chocolate manufacturers, confectioners and bakers. When cream of about 20% fat content is dried, the powder contains about 70% fat.

Malted Milk

The United States Department of Agriculture defines malted milk as "The product made by combining whole milk with the liquid separated from a mash of ground barley malt and wheat flour, with or without the addition of sodium chloride, sodium bicarbonate and potassium bicarbonate, in such a manner as to secure the full enzymic action of the malt action, and by removing water. The resulting product contains not less than 7.5% of butter fat and not more than 3.5% of moisture."

Malted milk was the first dry milk product made commercially in the United States. It was invented about 1883 and appeared on the market about 1887. Its manufacture was undertaken by Wm. Horlick, at the request of physicians who wanted a "baby food" prepared from milk and cereals.

Manufacture

The manufacture of malted milk involves two steps; the preparation of a malt extract and the mixing and drying of the extract with milk. Barley malt is generally employed but some use has been made of wheat malt. The barley is malted by soaking it in water and allowing germination to proceed to the point where its diastatic activity is at a maximum. Diastatic activity is a measure of the amount of diastase present, the enzyme which has the power to convert starch into sugar.

The finished malt is dried, mixed with wheat flour and passed through a crushing device and hot water is added. The diastase present converts the starch in the cereal grains into maltose and

dextrin. When this action is complete, the mixture is filtered, and whole milk is added in the ratio of about 1 pound of milk to 1¼ pounds of malt extract. A little common salt and usually some sodium bicarbonate is added, the latter to neutralize some of the acidity of the mixture. Finally, much of the water is evaporated and then the mixture is dried on a drum dryer. Some malted milk is made by the spray process.

Use of Malted Milk

Large amounts of malted milk are used in soda fountain drinks and other beverages, confections and baby foods. It is a popular food for invalids.

Nutritive Value of Malted Milk

Malted milk is a rich source of readily available carbohydrates. The cereal proteins originally present are partially digested during the malting process. Malted milk is a good source of mineral salts, vitamin A and those of the B complex. It furnishes about 145 calories per ounce.

Composition of Malted Milk

The composition of a number of samples of malted milk is shown in Table 19.

TABLE 19

Composition of Malted Milk

	Water %	Protein %	Sucrose %	Lactose and Maltose %	Fat %	Ash %
Maximum	3.2	14.3	8.1	45–55	8.8	3.9
Minimum	1.2	9.8	4.3	40–50	7.3	2.5
Average	2.6	13.0	5.2	42.5–52	7.8	3.0

Chocolate Flavored Malted Milk

Chocolate flavored malted milk products often are mechanical mixtures of cocoa, chocolate, sugar and malted milk. Sometimes considerable amounts of dry non-fat milk solids are added. A

wide variation in composition is found in the different brands of chocolate flavored malted milk. In most cases, the high sugar content makes them an unbalanced food from the nutritional viewpoint. An analysis of one widely sold product showed it to contain 40 to 50% of sucrose, 15 to 25% of malted milk, 15 to 25% of cocoa and chocolate, about 1% of salt and flavoring materials, such as vanillin and cinnamon.

CHAPTER 15

BUTTER: OLEOMARGARINE

Butter Manufacture

Dry non-fat milk solids and butter are defined by law. The Congress of the United States by an act, approved March 4, 1923, defined butter as follows: "Butter is the food product usually known as butter and which is made exclusively from milk or cream, or both, with or without common salt, and with or without additional coloring matter, and contains not less than eighty percent by weight of milk fat, all tolerances allowed for."

The recorded history of butter dates to the Hindu Veda, written over 3500 years ago. At that time the Hindus valued cows according to the amount of butter that could be obtained from their milk. Among the ancient Greeks and Romans butter was used as a medicine. The Romans preferred butter with a rancid flavor, rather than the fresh product. They also used it in ointments, applied it to the hair, and the soot of burned butter was supposed to have curative properties for sore eyes. The last observation is of some interest in view of the fact that when included in the diet, butter is a good source of vitamin A, which has a beneficial effect in some eye disorders.

Butter is a mixture of milk fat, buttermilk and water, usually with salt and added color. Its composition varies somewhat according to the method of manufacture and whether it was made from sweet or sour cream.

The steps taken in the manufacture of butter briefly are as follows:

Upon arrival at the plant, the cream is graded for quality and if too sour, the acid is neutralized by the addition of an alkaline compound, such as sodium bicarbonate, lime, magnesium oxide or hydroxide or mixtures of these compounds. After standardization to the desired fat content, color is added and the cream is pasteurized and then cooled to about 50°F. or lower.

Cream that contains from 30 to 33% of fat usually is preferred since too long a time is needed to churn cream of low fat content and some of the fat remains in the buttermlik. On the other hand, too rich a cream causes a fat loss since unchurned cream may adhere to the sides of the churn.

If the butter is to be made from ripened cream, the cream, after pasteurization, is inoculated with a culture of lactic acid-forming bacteria and allowed to ripen (see Chapter 10).

The cold cream is pumped into the churn, which is filled about one-half full and then revolved a few times in order to release the pressure in it caused by the escape of air and gases from

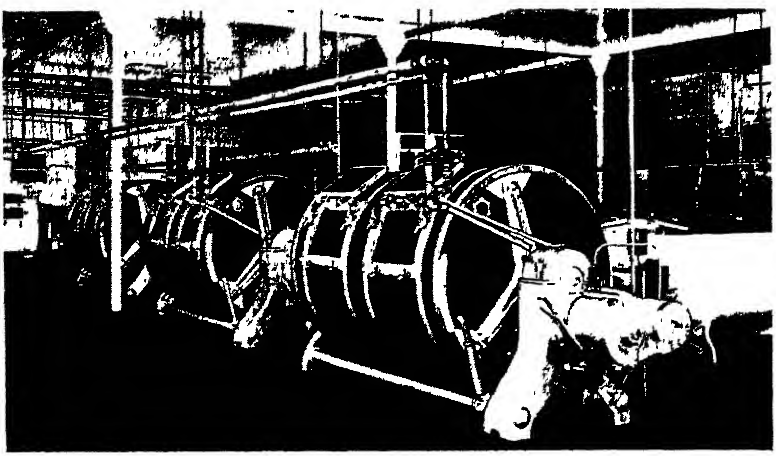


FIG. 47. *Churn Room in a Creamery*

Note Pasteurizing Vats to rear of Churns. *(Courtesy of The Creamery Package Mfg. Co.)*

the cream. A vent in the churn is provided for this purpose. Churning is then continued until granules of butter, about one-eighth to one-fourth inch in diameter are formed. Butter forms very quickly at the end of the churning process and is said to *break* as it separates from the buttermilk.

The buttermilk is withdrawn from the churn and water, at the same temperature or colder than the buttermilk, is added to wash the butter granules. After the wash water is drawn off, salt is added to the churn in the case of salted butter and the butter then is *worked*. Working is essentially a kneading process in which the butter granules are forced into a compact mass.

At this time any excess water or buttermilk is removed or, if necessary, additional water may be incorporated in order to control the moisture content of the butter. In the case of salted butter, the working process distributes the salt uniformly throughout the mass of the butter. Properly worked butter has a firm, waxy body which is not greasy and contains no visible droplets of water.

Butter Churn

The conventional butter churn is a wooden cylinder which is rotated on a horizontal axis. As the churn rotates it raises the cream by means of shelves attached to the sides of the churn. After the butter is formed, the continued raising and dropping of the butter from the shelves imparts the necessary working. Churns in common use are capable of producing 1000 or more pounds of butter within 2 hours.

The wooden churn, being porous, is difficult to sterilize and gradually wears out with use. The areas where the shelves are attached are favorite spots for the growth of microorganisms. Wood has been considered the standard material for churn construction since it is one of the few common materials to which butter will not adhere during manufacture and which will not impart a flavor to the product or be corroded by the milk or salt used.

The modern *all-metal churn* overcomes many of the difficulties inherent to the wooden churn. Butter will stick to most metals but the inventors of the metal churn found that aluminum alloyed with about 2 percent of magnesium was very suitable for its construction. The metal churn developed by the Challenge Cream and Butter Association of California is cubical in shape and rotates on axes attached to the two opposite corners. The churn is smooth on the inside and has no shelves. The cream is churned and the butter worked as it drops from one side of the churn to the other as it rotates.

Continuous Butter Making

New Way Process

Until very recently, the only way to make butter was to churn milk or cream. For many years experiments were carried

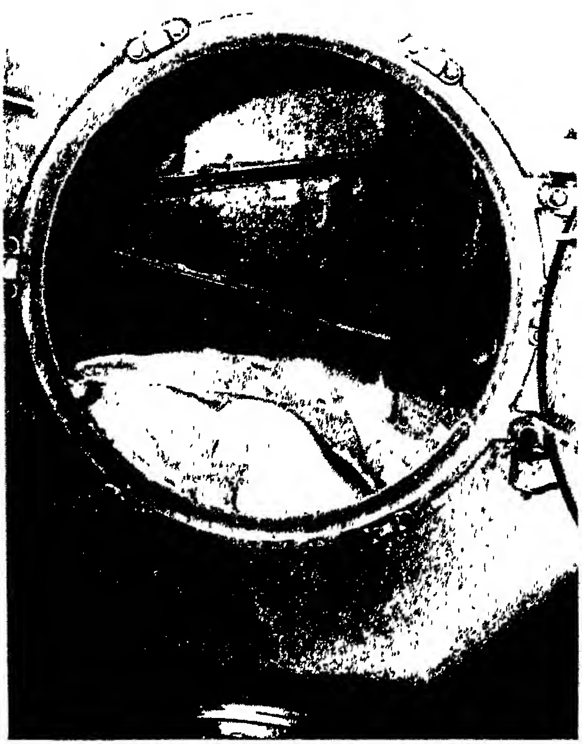


Fig. 48. *Interior View of Metal Churn, Showing Mass of Worked Butter (Courtesy of Gil Culver.)*

out in this country and abroad to make butter by some other method. Probably the first commercial manufacture of butter by a continuous mechanical process was made in Australia about 1937 by the "New Way" process.[188] In this process, flash-pasteurized cream is separated in a special type of separator so that a plastic cream of a little over 80% fat content is obtained. By means of a vacuum pump the cream, at a temperature of 140°F. is conducted to a vat. Here salt is added if salted butter is to be made and, if necessary, enough water is added to the cream to insure the correct moisture content in the finished butter. It will be noted that the standardized cream is identical in composition to the butter desired, but differs from it in physical condition.

Cream is an oil-in-water emulsion, butter, a water-in-oil emulsion; the oil in each case being milk fat. To change the phase of the emulsion, a machine known as an extruder is used in this process. Essentially it consists of two hollow cylinders, fitted with square-cut threads. The cylinders, which are brine cooled internally and also jacketed by a brine cooled cover, are gear-driven in opposite directions. Cream entering at one end of the cylinder is driven forward by the threads and at the same time is cooled rapidly. The combination of cooling and the working imparted by the action of the geared cylinders inverts the emulsion phase and changes the cream to butter. Actually, such butter differs somewhat from that obtained in a churn since it contains a little more curd and a higher phospholipid content.

A *New Way butter-maker* is shown in Fig. 49.

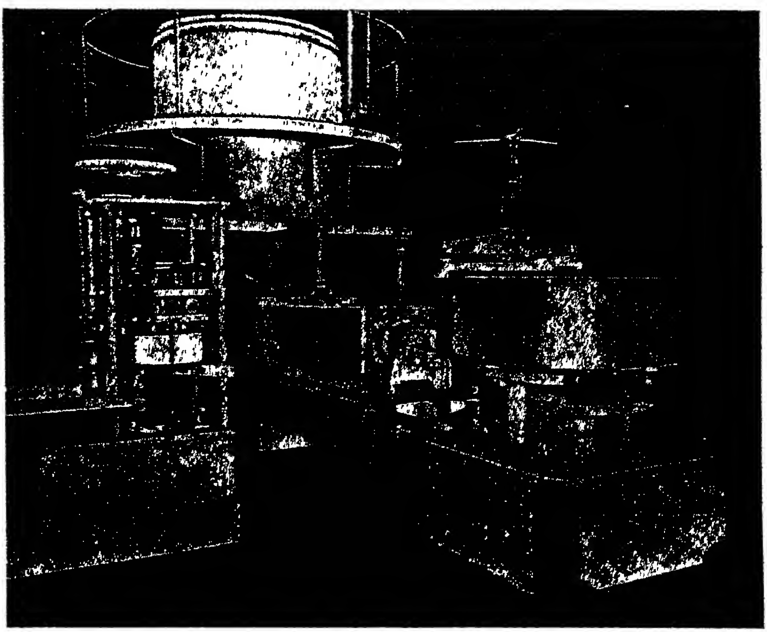


Fig. 49. *New Way Butter Maker*

The actual butter-maker is shown in the rear. Equipment in the foreground is used to cut and package the butter as it comes from the machine. *(Courtesy of James Bell Machinery Pty., Ltd.)*

German Developments

During World War II, continuous methods for making butter were developed in Germany.[172] In the Fritz process, cream actually is churned continuously in machines having capacities up to about 4000 lb. of butter per hour. Cream of 40 to 45% fat content is pasteurized at about 203°F., cooled to 45–50°F. and then pumped into the butter maker. In this machine, cream enters a water cooled cylinder (A) (Fig. 50) where it is churned into butter in about 1½ seconds by high speed dashers (B). The butter granules are separated from the buttermilk in another part of the machine (C) by the action of two intermeshed screws rotating in opposite directions. Buttermilk drains away through outlet (D).

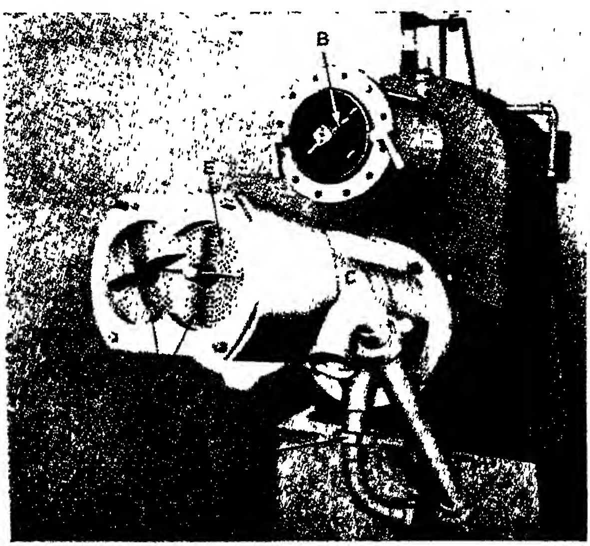


FIG. 50. *View of Fritz Butter-making Machine (British Intelligence Objectives Subcommittee Report 85.)*

From the separating chamber the butter passes through an adjustable rectangular opening into another compartment fitted with two screws, similar to those in the separator-unit. These screws force the butter through perforated plates (E), from the face of which it is removed and at the same time worked by

rotating scrappers (F). The butter is extruded through a rectangular opening in the end of the unit. The machine can be regulated so that butter can be made with a moisture content as low as 11% and as high as 20%.

In another process, the Alpha process, butter is made by a phase inversion method. Milk, pasteurized at about 203°F. is separated into cream containing about 78% fat in a special air-tight separator. This cream is cooled to about 68°F. in the bottom cylinder of a special three part cooling unit. These units are about 6 feet long and 1 foot in diameter; inside of each is a rotating drum (A) (Fig. 51). Mounted on each drum are spiral ridges (B). From the bottom cylinder, the cream passes to the middle cylinder where it is cooled to 48°–50°F. At this temperature, the oil-in-water phase is reversed to the water-in-oil phase characteristic of butter. The butter is too viscous to flow at the temperature of formation, so it is heated to about 57°F. in the top cylinder and from there is lead directly to containers. The water content of the butter is controlled by the pressure screw *C* which regulates the rate of flow and the fat content of the cream from the separator. Butter containing as little as 8% moisture may be made. The machine has a capacity of about 550 pounds of butter per hour.

It is claimed that the Fritz process can be used to make butter from sour cream, but in the Alfa method, sour or neutralized cream tends to clog the separator.

American Continuous Buttermaking Processes

During 1946, two American developments for continuous buttermaking were announced. Both processes make use of very heavy cream obtained from special cream separators. In the Cherry-Burrell process,[173] the cream used contains between 86 and 90% milk fat. The separator used has three discharges, one for the fat concentrate, another for skim milk and a third for the curd that is present when sour cream is separated. The fat concentrate is pumped from the separator to a vacuum pasteurizer or *Vacreator* where it is pasteurized continuously at a temperature range of from 190 to 200°F. The pasteurized cream is cooled to 110 or 115°F. while still in the Vacreator and then is collected in standardizing vats. These vats are of 200 gal.

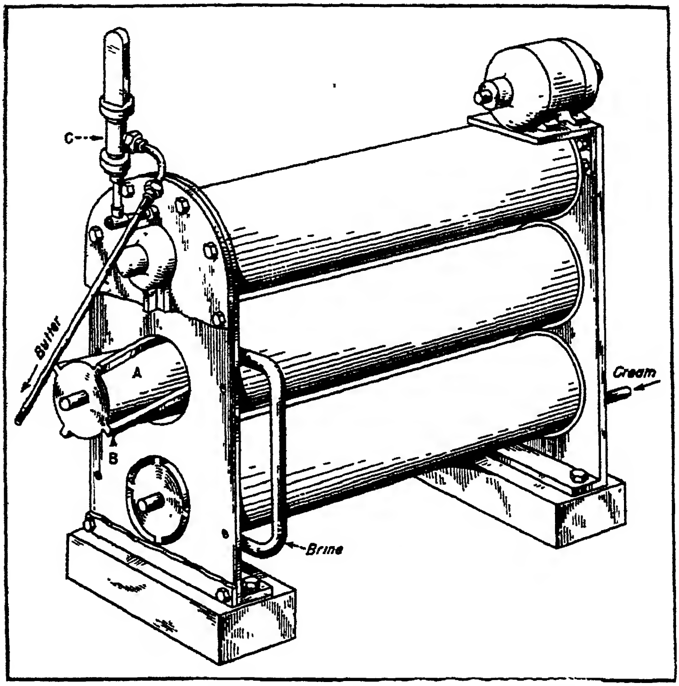


FIG. 51. *Alfa Continuous Butter-Making Machine*

End plate broken to show design of the rotating drums. *(From British Intelligence Objectives Subcommittee Report 85.) (Courtesy of Food Industries.)*

capacity and are equipped with special agitators which uniformly mix the salt and water added to the fat concentrate. When necessary, neutralizer may be added to the water and salt mixture. Color, if required, and a butter culture, if desired, may also be added at this time. After thorough mixing, a sample of the mixture is taken for analysis.

If the composition is correct, the standardized mixture is pumped under pressure through a chilling unit, similar in construction to a continuous ice cream freezer. Here the product passes through a series of tubes equipped with specially designed agitators. The action is such that the milk fat is chilled to about 40°F. and is partially worked. For further working and to prevent the butter from being hard, brittle or crumbly, the product passes directly from the chilling unit to a *Texturator* where the working is completed and the finished butter is ex-

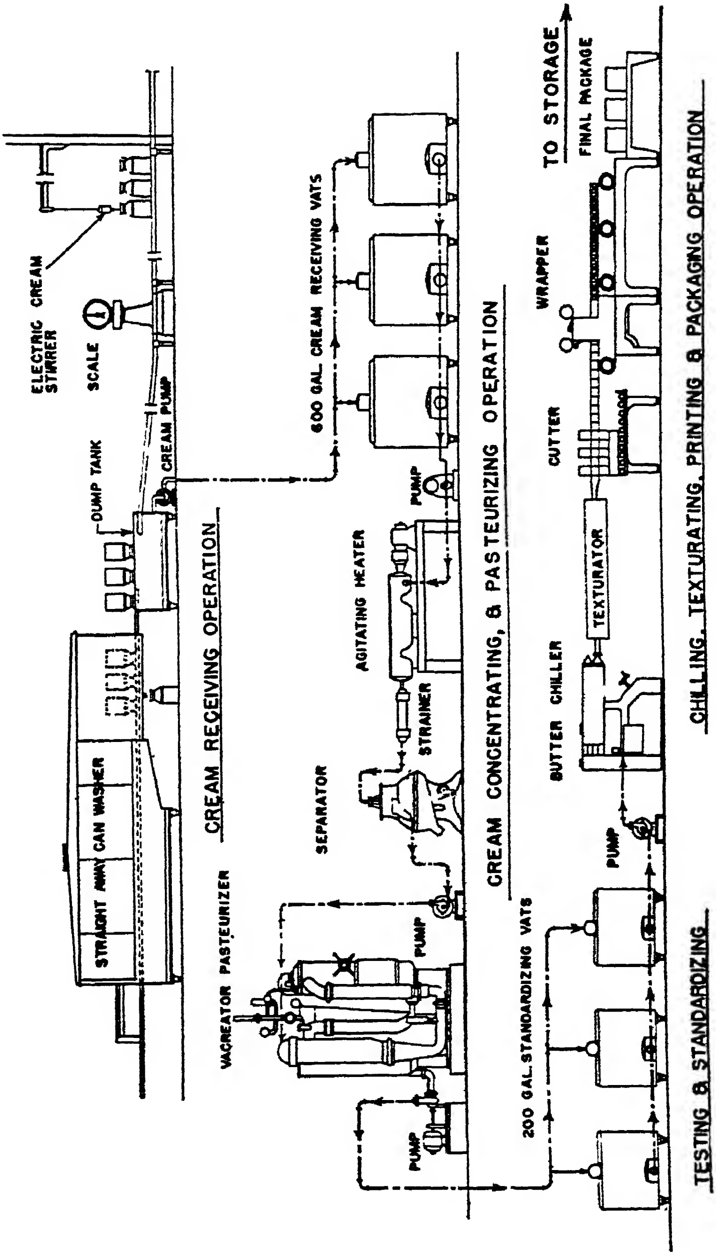


FIG. 52. *Continuous Butter-making Flow Diagram (Courtesy of Cherry-Burrell Co.)*

truded in a continuous stream, ready to be cut and wrapped into prints.

The continuous buttermaking process developed by the Creamery Package Company[174] uses heavy cream, containing 75 to 80% of milk fat. The hot cream is pumped through a homogenizer in which the fat phase is reversed so that a water-in-fat emulsion is obtained. In this case the use of the homogenizer has the opposite effect to that obtained in the homogenization of milk, in general. Hot cream of very high fat content is passed through the homogenizer, with the result that the fat globules form a continuous layer of liquid fat. The liquid fat and milk serum enter a separating chamber where the lighter fat fraction rises to the top of the chamber and the heavier serum fraction gravitates to the bottom. The serum is added to the incoming cream in order that any fat present is recovered.

The fat fraction is pumped to a composition control mechanism wherein it is mixed with a solution prepared from water and salt in such proportions that the mixture will have the composition of that desired in the finished butter. This mixture is pumped continuously to a chilling unit which is essentially a modified continuous ice cream freezer. The mixture enters the chiller at a temperature of 140 to 150°F. During its passage through the cooling chambers, the fat is converted to a plastic mass, and cooled to 45 to 55°F. It is worked until it acquires the body and texture of butter. The butter is discharged from the chiller through an extruding tube which has the cross dimensions of a standard print of butter. This is cut, wrapped and cartoned in a conventional manner.

Overrun

The weight of butter obtained from a given lot of cream exceeds the amount of fat in the cream. This is due to the presence of water, salt and curd in the butter. The amount of butter made in excess of the milk fat present in the cream is called *overrun.* Since the minimum legal fat content of butter is 80%, the maximum amount of butter that can be made from 100 pounds of milk fat is $\frac{100}{80} \times 100$ or 125 pounds. This is

an overrun of 25% but it is not obtainable in actual practice. Efficient creamery operators approach an overrun of about 23%, based upon the amount of milk fat going into the churn.

Composition of Butter

A chemical analysis of butter usually gives the percentage of fat, water, salt and curd present. The curd consists of protein, mineral matters and lactose derived from the buttermilk retained by the butter. The average composition of butter, based upon published analyses of more than 12,000 samples from various parts of the United States is given in Table 20.

TABLE 20

Average Composition of Butter

Fat %	Moisture %	Salt %	Curd %
80.47	16.34	2.35	0.84

Uniform methods of manufacture and the effort to keep the fat content near the minimum legal requirement are responsible for the little variation in the composition of butter. It is not unusual for creamery operators to pay a bonus to the buttermaker for each churning of butter in which the fat content does not exceed a certain maximum, say about 80.3%. Milk fat is by far the most expensive fat in common use as a food, but adulteration with other fats is very uncommon. Any adulteration would soon be detected by the inspections and tests given butter by various governmental health and food inspection agencies.

Flavor

The characteristic flavor and aroma, which usually are noted best when the butter comes fresh from the churn, distinguish it from other edible fats. Although its chemical composition may vary but little, the flavor of different lots of butter may show a considerable variation. To a large degree, the flavor of butter depends upon the quality of the cream used in its manufacture as well as upon the manner and length of time during which the butter was stored before consumption. Butter made from sour

or ripened cream has a distinctive flavor which is popular in some parts of the United States, while other sections, especially the west and north-west, prefer butter made from sweet (fresh) cream. Almost any foreign flavor or odor in the cream will be transmitted to the butter. Butter is an excellent solvent or fixative for many of the flavors and aromas to which it may be exposed or which may form in it by the growth of microorganisms.

Much of the desirable odor of butter and other dairy products is due to the presence of a very small amount of the compound known as biacetyl. This is a yellowish, oily liquid, traces of which are found in roasted coffee, honey, tobacco smoke and other aromatic substances. The biacetyl in milk products is formed by the action of bacteria, especially certain strains of lactic-acid fermenting organisms. These bacteria are able to convert some of the milk constituents, such as citric acid, into biacetyl.[139]

A tallowy flavor, more properly known as "oxidized" flavor, sometimes is present in butter and other products which contain fat. This defect is caused by a chemical change in the fat. In time, oxidized butter may become bleached and actually turn white. A rancid flavor, as has been explained in Chapter 6, is caused by the liberation of fatty acids from the milk-fat and should not be confused with oxidized flavor. Defects in flavor which are of bacteriological origin are discussed at the end of this chapter.

Grading Butter

Butter is classified into a number of grades according to its flavor, body, color and salt content.[175] In the scoring procedure used by the United States Department of Agriculture, the best grade of butter is known as *U. S. Grade AA* or *U. S. 93 Score*; below this is *U. S. Grade A* or *92 Score*. Butters of somewhat inferior quality are rated *Grade B* or *90 Score* and *Grade C* or *89 Score*. Butter of still lower quality may be graded *U. S. Cooking Grade* and finally there is a *No Grade* classification.

The judging of butter is an art that is practiced with a fine degree of distinction. Thus, *Grade AA* butter shall possess a fine, highly pleasing flavor. A slightly normal feed or a definitely cooked flavor may be present. Ten types of flavor or slight

flavor defects such as cooked, slightly storage, flat or acid, are allowed for butter that is graded 92 score. Any one of fourteen flavor defects, including those imparted by an excess of neutralizer, storage, bitter and old cream places butter in the *90 score* grade. No provision is made for a 91 score butter. Butter inferior to 90 score and possessing any of 15 flavor defects such as sour, cheesy or yeasty is placed under *Grade C.* There are 8 definitely undesirable flavors, such as fishy, pronouncedly yeasty or pronouncedly stale flavor which place butter in the *Cooking Grade.* Eight objectional flavors, including surface taint, tallowy, rancid, and chemical as well as conditions such as mold, splinters of wood or the presence of foreign materials place butter in the *No Grade* category.

Butter judges apparently agree that no lot of butter is perfect in all details and therefore do not give it a score of 100. A product of exceptionally excellent quality sometimes is given a score of 95 or 96 but practically all commercial butter of first quality is scored either 92 or 93 points.

Color of Butter

The natural color of butter is due almost entirely to its carotene content. Carotene is the yellow pigment found in many vegetables and fruits as well as in grasses and forage plants. In the animal body it is converted into vitamin A (see chapter 3). In naturally deeply pigmented butter, traces of other yellow-colored compounds may be present. Some cows, notably those of the Jersey and Guernsey breeds, can transfer more carotene from the feed to the milk than can cows of other breeds. Under ordinary conditions naturally colored butter is light in winter and a deep yellow in the early summer. This seasonal variation is caused by the difference between the high carotene content of fresh pasture feed during the spring and the carotene-poor feeds usually available in the winter months.

The seasonal change in color is objectionable to the consumer who prefers a uniformly colored product throughout the year and accordingly butter usually is colored artificially. The shade used varies locally, but in general, the northern and eastern states prefer a light, straw color, the southern states a deep yellow while in the western states an intermediate color is most popular.

Annatto, a yellow dyestuff obtained from the seeds of a tropical plant, often is used to color butter. Certain oil-soluble coal-tar dyes are also used since they are harmless and approved by the Federal Food and Drug Administration. Years ago, color made from carrots, saffron, marigold, and egg yolk was used to color butter. In any case, the color used is one that is fat or oil soluble since it must be retained by the milk fat. The color is added directly to the cream before it is churned.

The dye known to chemists as di-methyl-amino-azo-benzene and usually called "butter-yellow" owing to its color, never is used to color butter or other foodstuffs. Owing to its popular name, some misinformed persons have believed that the dye is used to color butter.

Butter Oil

A kind of clarified butter, more properly called butter oil, is used in many parts of India and Egypt. It is called *ghee* in India and *samma* in Egypt. Generally it is prepared from buffalo milk. The fresh milk is boiled for about one hour and then is allowed to stand in a warm place. Sometimes a little curdled milk (called dhye) is added to hasten coagulation. The curdled mass is skimmed off and churned for about one-half hour. Towards the end of this time, water is added and the churning continued until butter is formed. The fat is heated and strained, so that a clear butter oil is obtained. The method of manufacture removes much of the curd and moisture usually present in butter and also imparts a pronounced cooked flavor and odor to the product. It has good keeping properties, which is important under the climatic conditions of the Orient. Large amounts of it are used there for cooking and making confections. When made from cow's milk it often is used as a medicine, especially if it is old and rancid.

Clarified butter, made by melting butter and removing the curd and moisture, also is used to a considerable extent in Sweden and Switzerland. During recent years, butter oil, made by heating butter and removing the water and curd by means of a centrifuge, has become an important commercial product. Much is made in New Zealand and exported to Great Britain under the name of ***dehydrated butter.***

Butter Spread

A canned product called *butter spread* found much use during World War II in the tropical regions. Butter softens and spoils rapidly at the temperatures often found there but a satisfactory replacement was made by mixing butter with a small amount of cheese curd. This mixture has a melting point above 110°F., spreads well and its flavor, while not that of butter, is very acceptable.

Bacteriology of Butter

With the exception of the lactic-acid-forming bacteria introduced by the use of cultures, all bacteria, yeasts and molds are undesirable in butter. When made from unpasteurized cream, butter may contain any of the organisms present in the original cream or milk. Pasteurization of the cream destroys most of the organisms present but a few generally survive. Some of these are retained in the buttermilk, but others find their way into the butter. According to one investigator, about 15% of the bacteria originally present in ripened cream are found in the butter while from 5 to 30% are retained if it is made from sweet cream.[176] Disease producing organisms are able to survive in butter and the bacteria of tuberculosis and typhoid fever have been isolated from butter made from contaminated cream.

The activity of desirable flavor-producing organisms, such as are found in certain cultures used to ripen the cream for buttermaking, does not continue to any extent after the butter is finished. There is no evidence to show that the keeping quality of butter is related in any direct way to the number of bacteria, yeasts or molds that may be present. In fresh butter of good quality, the predominating organisms usually are streptococci and micrococci. During storage, the micrococci generally grow more rapidly than the streptococci.

Flavor Defect of Bacterial Origin

A number of flavor defects in butter are of bacterial origin. A *barny* or *cowy* flavor may be caused by the use of cream of

high bacterial content. A *bitter* flavor may be present if the cream had undergone bacterial decomposition. Butter made from sour cream or with the use of excessive amounts of starter may develop a *cheese-like* flavor and odor. This especially is true if large amounts of buttermilk are retained in the butter.

The presence of rod-shaped organisms in butter is very undesirable since they often are proteolytic and produce cheesy, putrid and unclean flavors and odors. It is claimed that the Aerobacter group produces more objectionable defects than does the Escherichia group, due probably to the fact that the former group grows more rapidly in either sweet or salted butter than do organisms of the Escherichia group.

Surface Taint

Bacteria introduced by the water used to wash butter during its manufacture may produce a cheesy flavor. Sometimes it is necessary to chlorinate or pasteurize the wash water in order to destroy the organisms. The flavor defect known as *surface taint* is associated with a bacterial contamination. The source can be the milk or cream from which the butter is churned, but the water supply appears to be in general the original source of contamination. The defect is characterized by a flavor and odor of putrefaction, which begins on the surface of the butter and gradually penetrates into its body. Butter made from cream of high acidity or butter that contains over 2% of salt rarely shows this defect. Proteolytic bacteria may be greatly outnumbered by harmless species and yet be present in sufficient number to produce surface taint. Under favorable conditions of temperature, salt and moisture concentration, the organism *Pseudamonas putrefaciens* produces surface taint but, undoubtedly, other organisms are also involved.[139, 177]

Churn Contamination

Churns are difficult to sterilize completely by ordinary plant procedures and require special attention if all contamination is to be eradicated. If not kept clean and sterilized, the churn can become an important source of contamination of the butter, especially with yeasts and molds.

Yeast and Mold Contamination

Butter made from cream that has undergone a yeasty fermentation may retain a characteristic and objectionable yeasty odor. The yeasts responsible usually are lactose-fermenting types, such as *Torula cremoris* and *T. sphaerica*. A fruit-like odor and flavor usually is caused by molds, but sometimes it is of bacterial origin. Defects of yeast and mold origin can be minimized by the use of a clean churn and pasteurized cream. Special vacuum treatment of the cream during pasteurization tends to reduce these and other objectionable flavors and odor defects if already present in the cream.[116]

Nutritional Value of Butter

The nutritional value of butter depends almost entirely upon its fat and vitamin content. The nutritional value of milk fat has been discussed in Chapter 2. The protein, lactose and mineral constituents of milk are almost entirely lacking in butter so that it is the most limited of dairy products in the variety of nutritive materials present.

Butter is a heat or energy producing food and furnishes about 3,400 calories per pound. Its digestibility usually is stated to be 97.8%, the value found for milk fat. Butter is an excellent source of vitamin A and often is the chief source of this vitamin in the diet. A survey of the vitamin A content of butter made throughout the United States showed that a pound of butter made between July and September contained an average of 18,000 International units of the vitamin, butter made in March may contain as little as 9,500 units.[178] The amount of vitamin D varies greatly. These factors are discussed in more detail in Chapter 3.

Margarine

No discussion of butter is complete without some mention of margarine. The prefix "oleo" is legally required by the Oleomargarine Act of 1886, but today, by far most of the products are made without the use of *oleo* oils or fats of animal origin.

Fundamentally, margarine is a substitute for butter because it is obtainable at a lower price than butter. Its price usually follows that of butter, going up when the cost of butter is high and dropping when butter is cheap, although the cost of the margarine ingredients may not have changed. The manufacturers of margarine try to associate their product with butter by stressing its milk content or illustrating their advertisments with yellow pats, even though most margarine is uncolored. Margarine usually is packaged in imitation of butter, being put up in a flat package where butter is so packed and in square packages in areas where square packages of butter are marketed.

Oleomargarine originated in France and became a product of importance during the Franco-Prussian War, about 1870. The name is derived from *margarine,* a substance at one time supposed to be a constituent of many fats but since shown to be a mixture of fatty acids. By definition, margarine may be described as a fatty product composed, wholly or in part, of fat other than milk fat together with water, skim milk and salt. Often about 0.1% of benzoic acid or sodium benzoate is added as a preservative. In many European countries sesame-oil, which is easily identified, or a small amount of starch must be added to oleomargine in order that the product may be easily distinguished from butter. This is considered necessary, since unlike in the United States, no tax or penalty is levied if the margarine is colored like butter.

A number of fats and oils are used in the manufacture of margarine. The principal ones used are coconut oil, soybean oil, cottonseed oil, oleo oil, oleo stock and neutral lard. Oleo oil is that portion of beef fat which is liquid at room temperature and oleo stock is beef fat rendered at a low temperature. Neutral lard is leaf lard rendered at a low temperature. Comparatively little animal fat is used today and none is present in vegetable or *nut* margarines. The kind of fat or oil used depends to some extent upon the preferences of the manufacturer but usually it changes from time to time depending upon the relative cost of the ingredients. About ten times as much cottonseed oil is now used as was ten years ago and soybean oil makes up about 44% of all the oil used. Some statistics on materials used in margarine are given in Table 40 in the Appendix.

Federal standards require that oleomargarine contains not less

than 80% of fat. It may contain sodium benzoate or benzoic acid as a preservative and be fortified with vitamin A or vitamin D. Usually it contains up to 3% of salt. In order to give it a butter-like flavor, biacetyl may be added and sometimes a special glycerin derivative is present to prevent spattering if the margarine is used for frying foods. No butter has been used in the manufacture of margarines for many years. About 85% of the products made today are fortified by the addition of vitamin A concentrate, so that the product may be about as good a source of this vitamin as is butter produced in the winter months. Generally 15,000 units of vitamin A per pound is added. If vitamin D is added, the margarine may be a better source of it than is butter.

Since margarine competes with butter, most states place a tax upon it and have legislation controlling its sale. The Federal government taxes oleomargarine 0.25 cent per pound if it is uncolored. If colored, to look like butter, the Federal tax is ten cents per pound, which makes the manufacture of colored margarine almost prohibitive (See Table 41).

The fats and oils used in the manufacture of margarine are mixed with ripened skim milk and the other ingredients until a complete oil-in-water emulsion is obtained. Often vegetable lecithin, derived from soybean, and glycerine derivatives are added to facilitate the formation of the emulsion. In contrast to margarine, butter is a water-in-oil emulsion. In the less modern factories, the fat emulsion is hardened by contact with ice water and the mixture is then worked in the same manner as in the manufacture of butter. In the newer method, the emulsion is chilled by passing it over a steel cooling drum or through a freezer and then kneading it in high-speed machines. The average composition of margarine is shown in Table 21.

TABLE 21

Average Composition of Margarine

Water %	Fat %	Salt %	Curd %
15.43	80.52	2.40	1.05

Margarine manufactured under modern conditions from clean, wholesome ingredients is a wholesome food product. It is not equivalent to butter or a complete substitute for it since it lacks

some of the constituents, such as certain fatty acids and vitamins, that are present in butter. The calorific value of margarine is practically that of butter, about 3300 to 3400 calories per pound. Its digestibility is slightly less than that of butter, most investigators reporting values between 93 and 97%.

There are no conclusive data to show that the use of fortified margarine instead of butter is in any way deleterious. However, according to present day knowledge, it appears that butter is preferable for growing children and perhaps for pregnant and nursing women.[179]

During recent years the consumption of margarine in this country has varied between 1.1 and 3.7 pounds per person, compared to 12.1 to 18.7 pounds for butter. Per capita consumption data do not give a complete picture of food consumption, for, as in this case, some people never eat butter and many people do not use margarine. The production and per capita consumption of margarine during recent years is given in Table 41 of the Appendix. According to one authority.

Chapter 16

CHEESE

Although many hundreds of kinds of differently named cheeses are made, it is stated that throughout the world there are in all not more than twenty distinct varieties of cheese. The names most commonly given to these are: Brick, Cacciocavallo, Camembert, Cheddar, Cottage, Cream, Edam, Emmenthaler (Swiss), Gorgonzola, Gouda, Hand, Limburger, Neufchatel, Parmesan, Pecorino, Processed, Romano, Roquefort, Sap Sago and Trappist.[181] Other names sometimes denote a slight variation of the manufacturing process of some definite variety of cheese. Cheese is defined as "the product made from the curd obtained from whole, partly skimmed, or skimmed milk of cows or from the milk of other animals, with or without added cream, by coagulating the casein with rennet, lactic acid or other suitable enzyme or acid, and with or without further treatment of the separated curd by heat or pressure, or by means of ripening ferments, special molds or seasoning. In the United States the name *cheese* unqualified is understood to mean cheddar cheese."

In the manufacture of cheese, milk is transformed into a concentrated and less perishable foodstuff. Most of the protein and fat of the milk is retained by the cheese but the more soluble constituents, such as the milk sugar and much of the mineral matter, are lost in the whey. On the whole, the manufacture of cheese is a rule of thumb process, wherein the results obtained depend to a great degree upon the skill and experience of the cheese maker. A possible exception to this statement is the modern method for making cheddar cheese from pasteurized milk by carefully controlled schedules and the methods of procedure.[182]

Cow's milk is used for the manufacture of the more common varieties of cheese made in the United States. Goat's milk, ewe's and mares' milk is used in various parts of the world for the manufacture of special types of cheese. Generally, raw milk is

used, but sometimes pasteurized milk is employed to make certain varieties and its use is gaining favor in this country.

Depending upon the kind of cheese to be made, the milk is coagulated either by the use of rennet or solely by lactic acid developed in the milk by the action of bacteria. The acidity in-

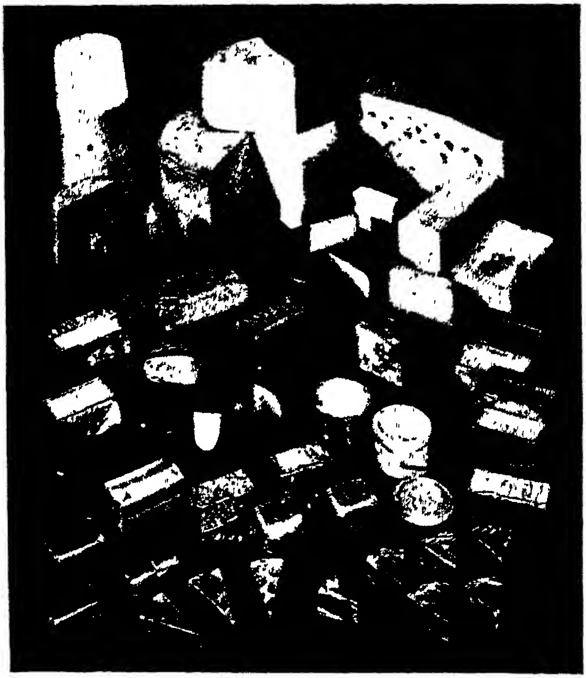


FIG. 53. *Cheese Varieties*

In the foreground are foil-wrapped packages of Philadelphia Cream Cheese, Cream Cheese, Limburger, Cheese Spread, Roquefort, Processed Loaf, Brick, Camembert, and Edam Cheeses. In the rear, Pineapple (a hard, cheddar type cheese), Longhorn (cheddar cheese), Cheddar or American and Swiss Cheese. *(Courtesy of National Butter and Cheese Journal.)*

fluences the rate of coagulation by rennet, since some acidity is needed to activate the enzyme. Cheddar type cheeses require the use of milk in which considerable acidity has been developed by lactic acid-forming organisms. After the curd has formed, it is cut into pieces in order to permit the whey to drain out mechanically. It also may be stirred, heated or pressed and placed in molds if a shaped cheese is made. Some cheeses, such as

cheddar, are salted while in the curd stage, other varieties are salted by rubbing the finished cheese with salt or dipping it into brine. In order to ripen properly, each variety of cheese requires storage under definite conditions of temperature and humidity.

Cheddar cheese usually is colored, the shade used varies from a pale yellow to a deep orange. Uncolored cheese has a pale amber or cream color, due, in part, to the fat present. Permitted coal tar colors are not popular with cheese makers; an alkaline, aqueous solution of annatto is generally used. Many cheeses, especially the soft varieties and Limburger, Swiss and Brick cheese are not colored artificially. Mold-ripened cheese, such as Roquefort, Gorgonzola and Stilton, contains seams and mottles of color due to the molds present. Other kinds of cheese, such as Edam and Parmesan, have their rind colored in a characteristic manner; the rind of Edam cheese is colored red, that of Parmesan is rubbed with oil and colored with lampblack.

Most varieties, with the exception of the cottage and cream cheese type, require an ageing or ripening period in order to give a palatable product with the required body and flavor. Fresh cheese is said to be green or uncured and has a tough, very firm and rubbery body and little flavor. One of the important changes that occurs during ripening is the conversion of a part of the insoluble protein into a water-soluble form by the action of enzymes contained in the milk, the rennet and the bacteria.

The formation of holes, known as *eyes,* is an important process during the ripening of Swiss cheese. Eye formation is caused by the collection of gas, which in normal cheese forms holes that are from ½ to 1¼ inches in diameter and spaced 2 or more inches apart. Cheese with very few holes, or with very many small holes has not undergone a normal ripening.

As already has been mentioned, the ripening process has an important influence upon the flavor of a cheese. In each type a characteristic bacterial or mold activity is associated with flavor production. Substances formed from the protein impart a distinct flavor and odor to the cheese. In some varieties, the fat is acted upon and the fatty acids and other compounds formed give the characteristic flavor, e.g., of Roquefort cheese. In old, well ripened cheese the sharp, pungent flavor may be caused by small amounts of ammonia. In Limburger cheese, bacterial action proceeds much farther in breaking down the protein than it does in hard

cheeses. Some varieties, such as Cottage and Neufchatel, undergo little ripening and their flavor is due to a lactic acid fermentation.

Cheese has been classified according to whether it is hard or soft and according to the manner in which it is ripened. This classification is shown in Table 22.

TABLE 22

Classification of Cheese[23]

	Soft Cheese	
Unripened	Ripened by bacterial action	Ripened by mold action
Cottage	Limburger	Camembert
Neufchatel		Brie
	Semi-Hard Cheese	
Ripened by molds		Ripened by bacteria
Gorgonzola		Brick
Roquefort		Münster
Stilton		
	Hard Cheese Ripened by Bacteria	
With gas holes		Without gas holes
Swiss		Cheddar
Parmesan		Edam

Nutritional Value of Cheese

All kinds of cheese contain approximately the same ingredients, but these vary in amount according to the type of cheese. Cheese is the most concentrated form of nitrogenous food commonly used. Practically all analyses report the nitrogenous matter as protein but this is not entirely correct since some of the original milk protein may be partially digested or be changed into protein-split products during the ripening process.

The fat content of cheese varies from almost 0% in plain, uncreamed cottage cheese, made from skim milk, to about 45% in cream cheese. Although cheese is a concentrated food, it does not contain all of the nutritive essentials of milk. Most of the milk sugar, milk albumin and soluble mineral salts remain in the whey. Certain special types of cheese, such as mysost and ricotta, are made from whey and so contain whey constituents rather than those of normal cheese. Some special cheese foods and spreads contain added whey or skim milk solids which supply nutritive ingredients missing in most forms of cheese.

In general, cheese made from milk coagulated with rennet is a good source of calcium and phosphorus, however, lactic acid varieties, especially cottage cheese, usually contain but little of these elements. About 80% of the calcium and 38% of the phosphorus of the milk is retained in cheddar cheese, while only 20% and 37% respectively is retained by soft cheese, as shown in Table 23. Since salt is added to cheese, the ash content may not give a correct picture of the original milk minerals present.

Most of the water-soluble vitamins of the milk remain in the whey, but vitamins A and D are incorporated in the cheese.

The analysis and calorific value of some varieties of cheese are given in Table 23.

TABLE 23

Approximate Composition of Certain Varieties of Cheese

	Moisture %	Fat %	Protein %	Ash %	Salt %	Calcium %	Phosphorus %	Calories per gram
Brick	42.5	30.6	21.1	3.0	1.8			
Brie	51.3	24 5	19.6	4.5				
Camembert	47.9	26.8	20.9	1.6	2.5			
Cheddar	36.0	33.8	24.2	3.4	1.0	0.84	0.53	4.68
Cottage (Uncreamed)	70–79	0.3–1.5	13–23	0.2–0.8	1.0	0.15	0.10	1.25
Cream	54.0	35.0	7.8	0.5	1.0	0.07	0.10	3.86
Devonshire Cream	31.6	61.0	4.4	0.6				
Edam	38.5	22.8	30.6	3.3	3.0	0.85	0.55	3.25
Gorgonzola	33.8	32.7	26.0	2.6	1.9			
Gouda	36.0	30.0	28 0	3.0	3.0			
Limburger	46.5	27.6	22.0	4.8		0.52	0.36	4.17
Neufchatel	55.0	25.0	20.0	0.8				
Parmesan	28.8	22.7	39.5	6.6	1.7			
Process	43.0	25.0	22.0	1.5	1.5			
Roquefort	39.5	33.0	22.0	2.3	4.2	0 55	0.36	4 06
Sap Sago	42.5	3 0	42.0	6.0	4.5			
Swiss	33.1	31.2	30.8	2.9	2.2			

Canned Cheese

A recent development in packaging cheese consists of sealing certain varieties of cheese in vacuum-sealed or valve-vented cans.[158] Freshly made cheddar cheese especially is adaptable to this procedure. Canned cheese undergoes no loss of moisture, has no rind

and may be sliced and packed in convenient sizes. When placed into well-filled, sealed cans, the cheese will not mold since the oxygen present is insufficient to support mold growth. The valve on the can permits the escape of gas that forms while the cheese ripens, but does not allow the air to enter.

Varieties of Cheese

A description of the principal varieties of cheese and the manner of their manufacture is given in the following pages:

Brick Cheese

This is a semi-hard cheese of American origin. Fresh milk is coagulated with rennet and the curd is cut as in the manufacture of cheddar cheese and then heated to about 115°F. The curd is drained and placed in molds. The finished cheese is about two to three inches wide, five to six inches high and about ten inches long. It is salted by rubbing the surface with salt or by soaking the cheese in brine for two or three days. During the ripening process, which is bacterial, and takes about two months, the cheese gets a rather soft texture and a waxy body. Its flavor and texture are between that of Limburger and Cheddar cheese.

Box Cheese

This cheese is similar to Brick cheese.

Brie Cheese

This cheese originated in France, where it has been made for more than 500 years. It is a soft, rennet cheese, ripened by molds similar to those that ripen Camembert cheese. Brie cheese made in the United States is partially ripened by bacterial action and dos not have the texture and flavor of the French product.

After the milk is coagulated with rennet, the curd is dipped into small forms and hoops and allowed to drain for 24 hours. The hoops are then removed and the surface of the cheese sprinkled with salt. The cheese is held in a dry, well ventilated room for about a week and is then put in a dark, moist room or cellar

for two to four weeks. During this time the cheese ripens and acquires a soft body, sharp odor and a characteristic flavor.

Caciocavallo Cheese

This cheese has been made in Italy for several centuries. The name, meaning "horse cheese" probably refers to the original place of manufacture, Monte Cavallo. It is a hard, rennet curd, bacterial ripened cheese made from cow's milk. After the curd is formed, it is cut into very fine pieces and heated in very hot whey or water. This treatment makes the curd plastic. In this condition the cheese is molded into the desired shape, usually like a bowling pin or bottle. It is salted by immersion in brine for two days and is afterwards lightly smoked. The surface may be rubbed with linseed oil or butter. The cheese usually is grated for use in soups or on macaroni.

Camembert Cheese

In 1928 a monument was erected to Jeanne Harel in Camembert, Normandy, France to commemorate her part in the origination of Camembert cheese in 1791. This cheese is made from cow's milk, coagulated by rennet. The curd is divided into small lots and allowed to drain for several days. Each cheese is then dusted with salt and placed in a cool room in which a high humidity is maintained. As the curd dries, mold growth appears on the surface of the cheese. From four to six weeks are needed to ripen the cheese.

Camembert cheese, made in this country, usually is inoculated artificially by sprinkling an aqueous suspension of the mold *Penicillium camemberti* on the cheese. This is considered unnecessary in France, where the air of the curing rooms contains sufficient mold spores to inoculate the cheese in a natural way.

Enzymes liberated by the molds act upon the protein of the cheese and ripen it by proteolytic action, working from the surface to the center of the cheese. The body of a well-cured cheese has the texture of soft butter. The surface generally is removed before eating the cheese, since it has a much stronger flavor than the body of the cheese. An odor of ammonia is apparent in an overripened cheese.

Cheddar Cheese

This cheese was first made in the village of Cheddar, near Bristol, Somerset, England. It is now, perhaps, the most universally made cheese and is called, in this country, *American Cheese.*

The milk is first heated to about 85°F. and 0.7 to 1.0% of its volume of starter is added in order to obtain a growth of lactic acid forming organisms. When the milk has acquired the proper acidity, about 0.2%, enough rennet (about 3 ounces per 1000 pounds of milk) is added to coagulate the milk in about ½ hour. Usually from 1 to 2 ounces of cheese color per 1000 lb. of milk is added. After the curd has formed, it is cut into small cubes,

FIG. 54. *Making Cheddar Cheese*

Here the curd is being matted or "cheddared" by cutting the curd, from which all the whey had been drained, into slabs. They are turned repeatedly until the right amount of acid has formed. *(Courtesy of National Butter and Cheese Journal.)*

¼ to ½ inch square. Special knives are used which have thin metal or wire blades. The cubes are stirred with mechanical agitators or wooden rakes while the temperature is raised to about 100°F. The heating is done by passing steam between the double walls of the cheese vat.

The whey is then drained off and the curd cubes, which by this time have shrunk to about one-half of their original size, are ready for the special process of cheddar cheese-making known as *cheddaring.* This consists of matting or piling the curd along the

sides of the vat and then cutting it into strips, allowing the particles to adhere to each other in order to form a solid mass or mat 4 to 7 inches thick. The mat, which is cut into blocks 7 to 10 inches long, permits the whey to drain off and also favors an even development of acidity. This procedure is necessary for the formation of the characteristic body and texture of the cheese. After cheddaring, the curd is ground in a mill, into small pieces, from ½ to 1 inch wide and 2 or 3 inches long. Milling also facilitates the escape of whey and permits even salting of the curd. The milled cheese is stirred for several minutes and then is salted. Cheddar cheese is one of the few varieties which are salted at this stage of manufacture. After salting, the curd is ready for pressing.

FIG. 55. *Milling the Curd*

Here the cheddared curd is being cut into small pieces. The four-pronged fork is used to stir the curd during the making of the cheese. *(Milwaukee Journal Photo.)*

At this point, the curd is put into tinned hoops or forms, lined with a tubular, seamless bandage of cheesecloth. The filled hoop is fitted with a top and placed in a press where it is subjected gradually to increasing pressure for 1 hour. The cloth bandage is then smoothly fitted over the cheese and the cheese is returned to the press for about 20 hours, during which time the excess moisture is removed from the cheese. After pressing, the cheese

FIG. 56. *Salting the Curd*

Salt is added directly to cheddar cheese curd. The salted curd is placed in hoops, which may be of various sizes and shapes, and then pressed for about 16 hours. The pressed cheeses are then placed in curing rooms until ripened sufficiently for sale. *(Courtesy of National Butter and Cheese Journal.)*

is placed on shelves in the curing room until the surface is dry and a rind is formed. It is then dipped into melted paraffin to prevent drying out and mold growth on the surface. The cheese is ripened at a temperature between 40° and 60°F. Because of the demand for a mild flavored cheese, it is often placed on the market within a few months after its manufacture.

Other varieties of cheese, such as *stirred curd, washed curd, Monterey, Jack* and *Granular* are made by modification of the cheddar cheese process. *Granular* cheese does not undergo the

FIG. 57. *Removing Cheddar Cheese from the Hoops after Pressing*

Cheese of this size is known as Twin Cheddar and usually are packed two to a case. These cheeses are ready for curing. *(Milwaukee Journal Photo.)*

cheddaring process; it has a higher moisture content and softer body than cheddar cheese and its keeping quality is not good. *Washed curd* cheese is similar to granular except that the curd is soaked in cold water before it is salted. This causes it to absorb much moisture and at the same time removes some of the more soluble cheese constituents. *Colby* cheese is a granular cheese of high moisture content.

Cottage Cheese

This is one of the most widespread varieties. It is a typical lactic acid, unripened, soft curd cheese. In some households it is made by allowing milk to sour naturally. *Dutch* cheese and *Schmeerkaese* (Smearcase) are other names for this cheese.

Cottage cheese is made commercially from skim milk. A little color may be added and some starter is used to promote lactic

acid fermentation. Often a small amount of rennet is added. The milk is allowed to set at 75°F. until the curd is formed. This is cut, stirred and gradually heated, as in the manufacture of cheddar cheese. After holding at about 100°F. for ½ to 1 hour, the curd is drained by placing it on frames fitted with cheesecloth. About 1 pound of salt per 100 pounds of curd is added.

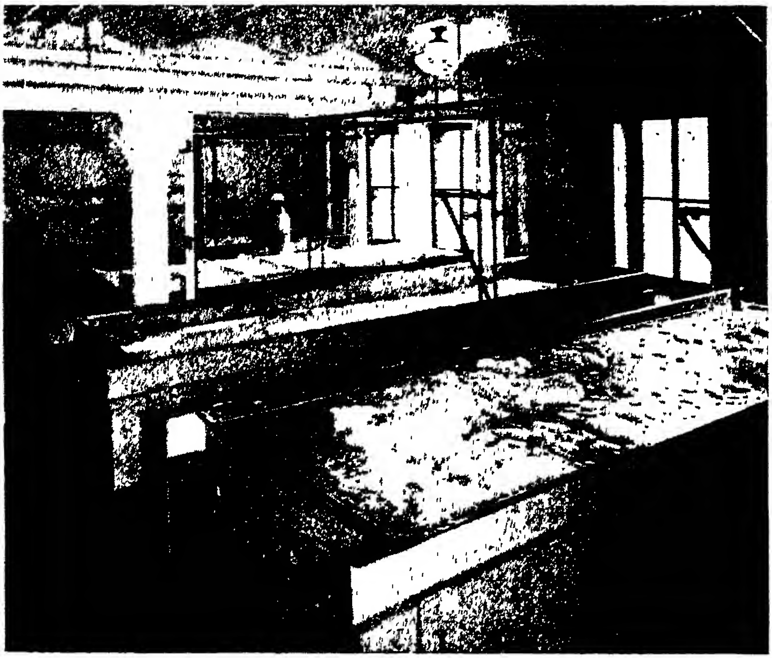


Fig. 58. *Cheese Vats in a Modern Factory*
(Courtesy of the Creamery Package Mfg. Co.)

If the curd is heated sufficiently to cause it to become rather dry, the cheese is commonly referred to as *farmer's* or *country style* cottage cheese. Cottage cheese made with the use of rennet is often called *baker's* cheese; when no rennet is used, it sometimes is called *pot* cheese. The curd particles of baker's cheese are usually somewhat larger and contain more moisture than those of cottage cheese.

The addition of enough cream to the cheese to bring its fat content up to about 4 or 5% materially improves its flavor. Such cheese is known as *creamed cottage cheese.* About ½% of gelatin

or vegetable gum is sometimes added to the curd in order to improve the body of the cheese.

The flavor of cottage cheese primarily is due to the activity of the lactic acid organisms used in the starter. The cheese has poor keeping quality and is readily attacked by molds and yeasts. It is a good source of milk protein, but a poor source of calcium and other milk minerals.

Cream Cheese

Some varieties of cream cheese are made in practically the same manner used for cottage cheese, except that rich milk or cream is used. The curd is not cut but is transferred carefully to a draining rack where the whey is allowed to drain off. The curd, placed in cheesecloth bags, is covered with cracked ice and pressed in order to remove excess moisture.

In another procedure, homogenized cream is used to which starter and rennet are added. A soft curd is formed which is heated to about 100°F. After the whey has separated, the curd is drained, salted and placed in bags covered with ice and pressed. This type of cream cheese, known as *Loaf Cream Cheese* has better keeping qualities than ordinary cream cheese due to the higher temperature used in its manufacture.

Pimento may be added to the cheese to make *Pimento Cream Cheese*. *Philadelphia Cream Cheese* is a trade name for cream cheese.

Devonshire Cream

This product is a form of clotted or thick cream. It is popular in parts of Cornwall, England, where it is used as a dressing or ingredient for salads, fruits and the like. It is made by placing milk in shallow pans and allowing the cream to rise. The pans are then heated at about 180°F. until a wrinkled skin spreads over the cream surface. After cooling and standing about twenty-four hours, the clotted cream is removed with a perforated ladle. Devonshire cream has a slightly granular texture and a cooked, nut-like flavor.

Edam Cheese

Edam cheese is a hard, rennet-curd cheese chiefly made in the northern part of the Netherlands where the town of Edam is a

famous market place for the cheese. The method of manufacture is very similar to that used for cheddar cheese, except that the curd is not allowed to develop any acidity nor is it cheddared or salted While still warm, the curd is placed into spherical molds, often made of wood. The pressed cheese is salted either by rubbing the surface with dry salt every day for a week or by immersing the cheese in a strong brine for several days. After curing in a cool room for about two months, the cheese is colored by dipping into a solution of a red dye. The surface is rubbed until smooth with linseed oil or is paraffined. Edam cheese has a dry, mealy body, with a somewhat salty flavor.

Gouda cheese is made in a similar manner but usually its surface is not dyed red.

Gorgonzola

This is a semi-hard, rennet curd, mold-ripened cheese, similar to Roquefort, of Italian origin. After the milk is coagulated by rennet, the curd is cut into small pieces, drained and placed in forms about one foot in diameter and ten inches high.

After a few days, growth of mold appears, at which time the cheese is salted by rubbing its surface with salt daily for about two weeks. The cheese is then pierced about 150 times with a metal skewer, about six inches long. The holes let air into the cheese and permit molds, similar to those of Roquefort cheese, to grow in veins and mottles throughout the interior of the cheese. The surface of the cheese often is coated with a colored mixture of gypsum and tallow in order to prevent mold growth on its surface.

Gruyère Cheese

This is a cheese made in French Switzerland by a process used for making Swiss cheese, but it is ripened differently. The surface of the cheese is moistened and a secondary fermentation occurs, during which the curd softens from the rind inwards and some protein decomposition occurs, which, with the formation of ammonia, gives the cheese a characteristic flavor and aroma.

Hand Cheese

This cheese is of German origin, and is so called because originally it was molded by hand into various shapes and sizes. Skim milk, often mixed with buttermilk, is allowed to sour and it then is heated to coagulate the curd. The whey is drained off and the curd is molded into cakes or balls. Salt, and sometimes caraway seeds, spices or beer, is added. The molded cheese is dried and then ripened in a cool, damp place where its surface becomes coated with a heavy growth of mold. About 2 months are needed to ripen the cheese. It has a sharp, pungent odor and flavor which is disagreeable to those who have not acquired a taste for the cheese. In some localities the cheese is known as *Bierkaese* or *Kuhkaese*.

Jack Cheese

Jack cheese often is called Monterey cheese since it first was made in Monterey County, California about 1892. It is an uncolored cheese, the curd for which is prepared in a manner very similar to that used for cheddar cheese. After it is salted, about ten pounds of the curd is wrapped tightly in a heavy muslin cloth, about 34 inches square, and pressed overnight. A thin, flexible rind forms on the cheese. After drying a few days, the cheese is dipped in melted paraffin, and after ripening for about one month, is ready for the market. Much jack cheese, made from skim milk, is dried and then used for making grated cheese.

Junket

Junket is a very simple form of soft, rennet cheese. It is often made at home by curdling milk with junket tablets, which contain rennet in a dry form. It is used as a dessert or in the diet of invalids.

Limburger Cheese

This soft, rennet curd cheese derived its name from the town of Limburg in Belgium. Very little, if any, Limburger cheese is

imported into the United States, since domestic manufacture supplies the demand.

Milk, heated to about 93°F., is coagulated with enough rennet to form a jelly-like curd in about 40 minutes. The curd is cut, stirred for a short time and then dipped into rectangular forms, 5 inches wide, 8 inches deep and from 10 to 30 inches long. The next day, the cheese is cut into one or two pound bricks which are rolled in salt and placed in a cool room with a high humidity for ripening, which takes about two months.

The cheese is ripened by bacterial action and its characteristic strong odor and flavor is due to the protein decomposition that takes place.

Neufchatel Cheese

Neufchatel is a soft, rennet curd cheese, made in a manner very similar to that used for cream cheese. The genuine cheese, made in France, is ripened until it acquires a characteristic flavor and the rind is blue-green with the growth of molds. It usually is packed in small, cylindrical form, about 3 inches long and 2 in diameter.

Parmesan Cheese

Parmesan cheese is a hard cheese of Italian origin. In Italy it is called *Grana* in reference to the granular structure of the surface when the cheese is broken. The cheese is made from partly skimmed milk by a method very similar to that used for Swiss cheese. The surface of the cheese is rubbed with salt over a period of several weeks after which it is treated with oil. The cheese may be stored for several years and becomes so hard that it cannot be cut. It is grated for use with macaroni and in soups.

Pecorino

This is an Italian cheese made from ewe's milk, coagulated with rennet. The curd is heated with hot water, which gives the finished cheese a flaky texture. It is salted by immersing in brine and also by rubbing its surface with salt until as much

as 7% of salt is incorporated. The cheese is ripened in a fairly warm room for about eight months.

A similar cheese made from cows' milk is called *Provolone* if pear-shaped and *Provola* if round.

Process Cheese

Process cheese is a product made by blending different lots of cheese with the aid of heat and an emulsifying agent.[184] Up to very recently, it was made by only a few manufacturers since the method was protected by basic patents but these have expired, and process cheese is now made in many places. Cheeses of varying degrees of ripeness, or too low fat content, or too high moisture content, or those having an off-flavor or other defect can be made marketable by processing.

Cheddar, Swiss, Limburger, Brick and Camembert varieties may be processed. Commonly, about 10% of old, well-ripened cheese is mixed with others 4 to 7 months old in order to give the finished product a desirable flavor. Considerable skill is needed to select cheese of the proper age and to regulate the manner of processing.

Generally, the first step in the process is to clean the surface and grind the cheese. Often about ½% of common salt is added. A small amount of emulsifying agent (up to 3%) is dissolved in water and added to the cheese. Sodium citrate, ammonium citrate, disodium phosphate and Rochelle salt are among the most commonly used emulsifying agents. Their use gives the cheese a plastic body and prevents the fat from separating during the processing. The mixture of ground cheese, emulsifier and water is heated to about 150°F. and stirred constantly until the desired consistency is reached. The hot, plastic mass is run through a special filling machine into containers lined with metal foil or moisture-proof paper. These are filled and sealed in such a manner that the package is airtight and the product will keep for a long time without mold development.

Roquefort Cheese

This is a semi-hard cheese, mold-ripened and characterized by a mottled or marbled blue-green appearance. It originated in the

village of Roquefort, Aveyron, France. The genuine cheese is made from ewe's milk to which a small amout of goat's milk may be added. When made from cow's milk the cheese lacks the characteristic strong flavor of the genuine product.

After the milk has been coagulated with rennet, the curd is cut into small pieces and placed in hoops about 8½ inches in diameter and 3½ inches high. When one-third or one-half full of curd, a thin layer of finely ground moldy breadcrumbs is spread over it. The crumbs carry spores of the mold known as *Penicillium roqueforti.* Two or three layers of curd and crumbs are used to fill the hoops. After standing two or three days, the surface of the cheese is sprinkled with salt. The salting is continued daily for five to ten days. Each cheese is then pierced with a large number of small holes which permit enough air to enter to allow mold growth in the interior of the cheese.

The ripening of genuine Roquefort cheese is done in natural or artificial caves whose temperature is around 50°F. and where the relative humidity is high, about 90%. Depending upon the degree of ripening desired, the cheese is ripened from one to six months. During this time the mold spreads through the crevices and perforations in the body of the cheese and lines it with greenish or bluish streaks of growth. The high salt content of the cheese prevents the growth of bacteria and restricts the ripening process to that produced by the molds. Fatty acids, chiefly capric, caproic and caprylic acids, are liberated from the milk fat by the action of lipase and give the well-ripened cheese its characteristic peppery flavor and aroma.

Imported varieties of blue-streaked cheeses, which are similar to Roquefort, but made from cows' or goats' milk are *Auvergne bleu, Septmoncel* and *Gex Bressons.*

Blue or Iowa Blue Cheese

This is a domestic variety, made by a patented process from homogenized milk, heated to about 170°F. and then cooled quickly to avoid destruction of the lipase naturally present.[185]

Sap Sago

This is a hard, gray-green cheese, made from sour skim milk. It has been made for over 400 years in Switzerland. A mixture

of skim milk and buttermilk is allowed to sour and then is heated to boiling. The whey is drained from the curd, which is placed in wooden troughs to cool. The drained curd is ripened over a period of several weeks. It is then ground to a smooth paste and from 4 to 5% of salt is added as well as about 2.5% of dried, aromatic clover leaf. This plant, *Melilotus Trigonella coerulea,* is grown especially for this purpose, mostly in the Canton Schwyz. The cheese is packed tightly into molds, pressed and dried until it is very hard. It usually is eaten in grated form, mixed with butter and spread on bread.

The cheese also is known as *Green Cheese* and *Kreuter Kaese.*

Stilton Cheese

This well known mold-ripened cheese got its name from the English village of Stilton, in Huntingdonshire, although it first was made in Leicestershire, which still is the chief place of its manufacture. The cheese is made from cows' milk and is not so strong in flavor as Roquefort or Gorgonzola. Unlike in the manufacture of Roquefort cheese, mold growth is not promoted by piercing the cheese with holes, but by keeping the pieces of curd from completely matting, thus making a space between the curd particles which admits enough air to maintain mold growth. The cheese has a characteristic wrinkled surface, probably caused by the drying of molds and bacteria on the rind.

Swiss Cheese

Swiss cheese, also known as Emmenthaler cheese, is a hard, rennet curd cheese, characterized by the presence of holes or *eyes* and a mild, somewhat sweet flavor.

The milk is heated in large kettles to a temperature of around 95°F. and enough rennet is added to coagulate it in about one-half hour. The curd is cut into small pieces about the size of grains of wheat with knives, known as "Swiss Harps," which are similar to those used to cut cheddar cheese. The curd then is heated, with constant stirring, for about an hour at a temperature of about 130°F. The removal of the curd from the whey involves a procedure peculiar to the making of Swiss cheese. A heavy cloth is placed over a hoop, and the contents of the kettle are set

FIG. 59. *Making Swiss Cheese*

Swiss cheesemaking progresses kettle by kettle, with the cheesemaker constantly on the alert to start each new step at the right time. Here one cheesemaker (rear) turns over the layer of butterfat, preparatory to cutting into inch squares the curd that has solidified to the proper degree. A second (left) "harps" the cut curd into particles the size of wheat grains. A third (right) tests the harped curd for the "break". If when firmly compressed in the hand the curd breaks as it should, it is ready to be drawn, or "dipped," from the kettle. *(Courtesy of National Butter and Cheese Journal.)*

into vigorous circular motion at this time. The motion of the curd is then quickly stopped by means of the stirring implement, which permits the mass of curd to collect into a spinning cone, at which time the hoop with its cloth is inserted beneath and the curd is lifted out of the kettle by means of a chain and pulley attached to the hoop.

The cheese is placed in a press for about a day, in order to remove excess moisture and aid in the formation of a strong, uniform rind. The cheese is then moved to a room held at a temperature of about 53°F. and is salted by immersing it in strong brine or rubbing it with dry salt over a period of two or three days. After salting, the cheese is moved to the curing room, where

the temperature is around 70°F. and the humidity is high. At this time bacterial activity becomes apparent and the holes or eyes begin to develop. Ripening may continue for several months, during which time an experienced cheesemaker can follow the development of the eyes by tapping the cheese with his finger and even can judge their size and location by the sound made.

FIG. 60. *Lifting Swiss Cheese Curd from the Kettle*

Hoop at right is ready to receive the curd. *(Courtesy of The Borden Co.)*

A well developed cheese has comparatively few eyes, and they range from about one-half to one and one-half inches in size. A cheese with many small holes or one with only large holes near the surface has not undergone proper development. The Swiss normally export cheese with large eyes to the United States. Swiss cheeses usually are very large, being made in "wheels" about six to eight inches thick and up to four feet in diameter, weighing from sixty to over two hundred pounds.

Trappist Cheese

This cheese originally was made by the Trappist monks in their monastery at Mariastern, Bosnia. A similar cheese is made by

Trappists in other places, such as *Port du Salut* in France and *Oka*, Canada, and the cheese is named after these towns. It is made by a process similar to that used for Brick cheese, except that the milk is heated somewhat higher and a longer time is taken for coagulation. The cheese is salted by immersing in brine in order to prevent mold growth. It has a firm rind and a soft interior, approaching Brick cheese but with a flavor more nearly like that of Limburger.

FIG. 61. *A Good Swiss Cheese*

This 200-pound Swiss Cheese was cured for three months. Eyes start to form two or three weeks after the cheese goes into the curing room. As curing progresses they grow in size until they are about as big as a quarter. *(Courtesy of National Butter and Cheese Journal.)*

Whey Cheese

The whey obtained from the manufacture of cheese is heated to coagulate the albuminous material. In order to hasten this reaction, sour whey or vinegar is sometimes added. The curded albumin rises to the surface and is skimmed off and the remaining liquid is evaporated to about one-fourth its original volume. The albumin previously removed is stirred back into the liquid and the entire mass is poured into a form or trough where it is stirred until cold. Whey cheese made by this method is known as

Mysost in the Scandinavian countries. When made from separated albumin alone, the cheese is known as *Ricotto* and *Ziger.*

Bacteriology of Cheese

The method used for the manufacture of a cheese has a great influence upon the number and type of organisms present. If the cheese is made from raw milk, any pathogenic organism present may survive. Several epidemics, especially of typhoid fever, have had their origin in the consumption of contaminated cheese. A number of States now require cheese to be made from pasteurized milk, unless the cheese is ripened for a period of 60 days or more, during which time it is assumed that any pathogenic organism may die.[135]

In the finished cheese, the bacteria are fixed in their position by the curd and so are limited in their area of growth. In each type of cheese the ripening process to which its flavor is due, is associated with the growth of characteristic bacteria or molds. In an acid-curd cheese, such as cottage cheese, in which little or no ripening occurs, the flavor is due largely to a lactic acid fermentation.

During the ripening process the protein in the cheese is broken down to simpler nitrogenous substances, many of which have a distinct flavor and odor. Certain non-nitrogenous compounds, such as volatile acids and esters, are formed when the fat is attacked; acetic, propionic, capric, caprylic and lactic acids are among the acids found. A rancid flavor, due to the presence of butyric acid, often is found in old cheese. Small amounts of biacetyl and related compounds are present in some cheeses, especially those of the cheddar type.

Bacterial activity neither plays an important role in the flavor development in unripened soft cheeses, such as Neufchatel and Cream cheese nor does it have any important part in the ripening of mold-ripened cheese. In Roquefort cheese the action of the lactic acid organisms is inhibited by the high salt content of the cheese as well as by the low temperature at which the cheese is cured. Other bacteria, such as *L. bulgaricus,* may be present, but they are not involved in the ripening of cheese of the Roquefort type.

Bacteria in Cheddar Cheese

At least six types of bacteria predominate in cheddar cheese. *S. lactis,* which is introduced with the starter, prevails while the cheese still is green. As the cheese ripens, this organism is replaced rapidly by other bacteria. *Lactobacilli*, such as *L. casei* and *L. bulgaricus,* predominate in ripe cheddar cheese of good quality. *Cocci* are found in cheese of both good and poor grades but spore-forming organisms are most frequently found in cheese of poor quality. They do not appear to influence the normal ripening process but are associated with the development of undesirable flavors.

The number of bacteria in cheddar cheese varies greatly, but usually between forty million and six hundred million are found per gram of cheese and as many as one hundred billion per gram may be present.

Bacteria in Swiss Cheese

Lactic acid and propionic acid-forming bacteria, streptococci and lactobacilli are important in the ripening of Swiss cheese. *S. lactis,* which is present at first, disappears rapidly, especially during the heating the cheese undergoes while still in the kettle. The growth of *Streptococcus thermophilus* is important since this organism favors the production of acid which prevents the growth of other organisms which might spoil the cheese. Bacteria, such as *Bacterium acidi propionici,* which form propionic acid and evolve gas are associated with the formation of the holes or eyes in Swiss cheese. These organisms do not grow while the cheese is in the press but generally increase in number during the cooking process. Their growth is increased in the presence of *S. lactis* and the *lactobacilli.*

Bacteria in Processed Cheese

The organisms in processed cheese are chiefly of the lactic acid type, but the types depend upon those in the original cheese as well as upon the time and temperature used in processing the cheese. Aerobic, spore-forming organisms, such as *B. mesen-*

tericus and *B. subtilis*, may be present as well as anaerobic, butyric acid-forming bacteria, since the temperature needed to destroy them is so high that it would affect the quality of the cheese.

Cheese Defects of Bacterial Origin

A *bitter flavor* usually is caused by the presence of protein decomposition products. This condition is favored by insufficient development of acid in the milk from which the cheese is made. In unripened cheese the defect may be caused by undesirable types of lactic-acid-forming streptococci or to volatile acids produced by anaerobic spore-forming bacteria. The bitter flavor generally becomes more pronounced as the cheese ages A low salt content in the cheese favors the development of a bitter flavor.

A bitter flavor in the milk, due to the cow's feed, may be carried over to the cheese. Occasionally a bitter flavor may be caused by the presence in the milk of the wild yeast, *Torula amara*.

A fruit-like flavor often is caused by bacterial contamination from unclean milk or equipment. Low acidity, caused by excessive washing of the curd, tends to favor the development of this defect.

Gassy Cheese

It has been found that practically all of the gas formed normally in cheese is carbon dioxide. Hydrogen sulfide, which has the odor of rotten eggs, is found in cheese that has undergone an abnormal fermentation, especially if the cheese had been ripened at too high a temperature.

A gassy cheese is characterized by the presence of many round holes which usually are regular in shape but vary in size. The bacteria commonly associated with gas formation belong to the coliform group. The use of starters to ripen the milk will suppress the production of gas by these organisms. During ripening, gas formation usually is caused by butyric acid-forming organisms.

In general, conditions that favor acid development in the cheese restrain gassy fermentations. Such conditions are obtained by the use of fresh cultures and the development of high acidity in the curd before the whey is removed. The use of more salt than usual sometimes will check undesirable fermentations. The

addition of a small amount of sodium or potassium nitrate to the milk has been recommended for the control of gassy fermentation, but this may cause a pink discoloration in the cheese.

Gassy fermentations in Swiss cheese are known as *nissler* and *pressler* fermentations. A nissler cheese has many small eyes or *pinholes* distributed throughout its body. This condition develops after the cheese is made and is caused by contamination with anaerobic spore-forming bacteria. Cheese that has not undergone proper acidity development often shows this defect. Swiss cheese that is made from the curd left in the kettle, the so-called *streble,* frequently forms a nissler cheese. A pressler cheese has large gas holes, usually near the surface.

CHAPTER 17

ICE CREAM

The first recipe for ice cream was printed in England in 1769 in *The Experienced English Housekeeper*, by Elizabeth Raffield. In this country, ice cream was advertised for sale in the New York *Post Boy* of June 8, 1786 and has since become one of our most important milk products. Dairy statistics indicate that about 4½% of the total milk production of the United States is used in the manufacture of ice cream. About 475 million gallons of ice cream were made in the United States in 1945. Commercial ice cream is essentially an American product and comparatively small amounts are used in countries not touched by American influence.

The basic ingredients of ice cream are cream, milk, sugar and flavor. Gelatin or another stabilizer, color and sometimes egg yolk are added. Milk and cream alone do not contribute enough milk solids-not-fat for commercial ice cream and they must be supplemented with condensed or dry non-fat milk solids. The entire combination, known as the *mix*, is pasteurized by heating to 150° to 165°F. for 30 minutes and is then homogenized and cooled quickly to about 40°F. before it goes to the freezer.

The fat in an ice cream mix comes chiefly from cream, sweet butter or butter oil and gives the product a rich flavor and improves its body and texture. The milk solids-not-fat or serum solids may come from milk, condensed skim milk, evaporated milk or dry non-fat milk solids. The serum solids contribute to the flavor of the ice cream, impart a desirable texture and play an important part in the overrun obtained.

Sugar not only adds to the sweetness of ice cream but it also lowers the freezing point of the mix so that it does not freeze to a solid mass in the freezer. Cane or beet sugar and to some extent dextrose (corn sugar or cerelose) is used. The milk sugar in the serum solids adds but little to the sweetness of ice cream.

At one time it was a common practice to hold or age the

homogenized mix at a temperature of 32° to 40°F. for four to twenty-four hours in order to permit clumping of the fat globules and to increase the viscosity of the mix. This procedure allows the mix to freeze more quickly and gives the ice cream a better body and texture. It is of value when ice cream is made with a fat content of 15% or more and when little consideration is given to the other milk constituents. The modern method of using a mix of high milk solids-not-fat content has made a long aging period unnecessary.

The Ice Cream Freezer

The commercial ice cream freezer consists essentially of a cylindrical chamber surrounded by an insulated jacket. A dasher or beater and a scraper driven by a motor at 130 to 240 rotations

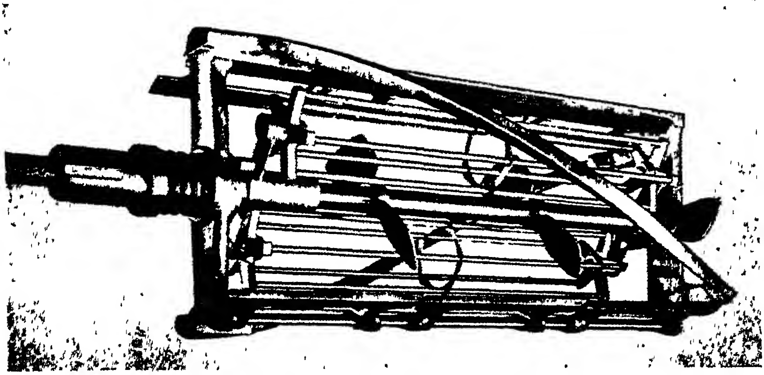


Fig. 62 *Dasher and Scraper Assembly of a Modern Ice Cream Freezer*

The curved scraper knives and the propeller-like blades and beaters revolve in opposite directions. *(Courtesy of The Creamery Package Mfg. Co.)*

per minute revolve in the cylinder. The principal function of the dasher is to incorporate air into the ice cream and also to remove rapidly the film of frozen ice cream from the walls of the freezer and to mix it thoroughly into the ice cream by forcing it towards the center of the freezer. The scrapers, sharp edged blades, remove any ice cream frozen to the sides to the freezer.

Three types of freezers are in common use. In the brine freezer, freezing is accomplished by the circulation of brine through the jacket of the freezer, at a temperature of 0° to 10°F. below zero.

In the direct expansion freezer, ammonia gas or some other refrigerant expands within the jacket, thus furnishing direct refrigeration. A freezing temperature of 10° to 15°F. below zero commonly is used. The small counter freezer, used in many stores, usually is of the direct expansion type. The continuous freezer is a modern development and consists of a freezing unit through which controlled amounts of ice cream mix and air are pumped continuously. *Soft* ice cream emerges after the first 10 to 15 minutes of freezing. The rapid freezing favors the formation of small ice crystals and produces a smooth texture in the ice cream.

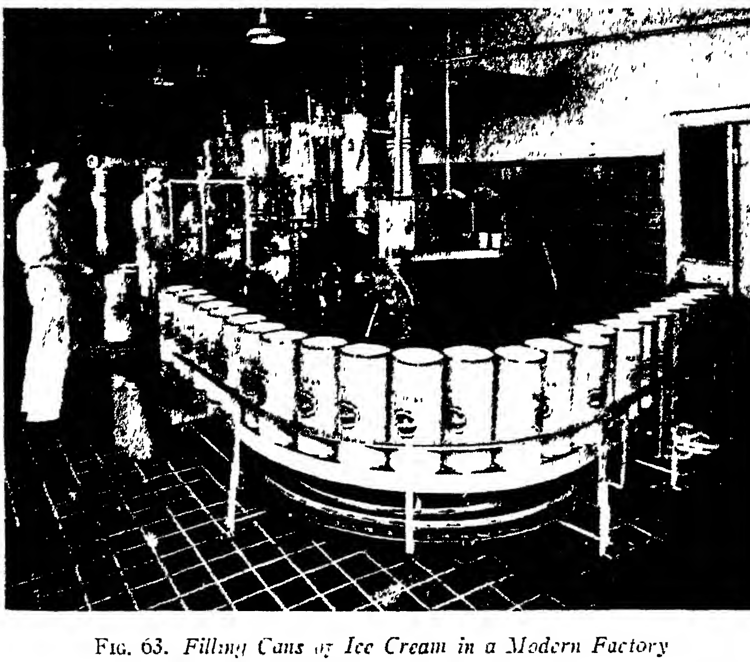


FIG. 63. *Filling Cans of Ice Cream in a Modern Factory*
A battery of continuous freezers in operation. Note vats, which contain the mix, extending through the ceiling from the upper floor. *(Courtesy of Mojonnier Bros. Co.)*

Sandy Ice Cream

The crystallization of lactose (milk sugar) in ice cream sometimes gives rise to the defect known as *sandy* ice cream. If more than about 11% of milk solids-not-fat are present the tendency

of lactose to form crystals is increased. *Heat shock* or the melting and refreezing of some of the ice cream in the dealer's cabinet is another factor that favors the crystallization of lactose. The crystals are not immediately noticeable in the frozen ice cream but when it melts in the mouth the crystals become evident and give the sensation of particles of sand or grit.

Stabilizer

In order to obtain an ice cream of satisfactory body, texture and overrun, small amounts of gelatin or another *improver* or *stabilizer* are added. These materials also prevent the formation of large ice crystals and increase the resistance of the ice cream to rapid melting. Gelatin is usually favored, but other substances, such as sodium alginate, which is derived from sea weeds, or vegetable products, such as gum tragacanth, karaya gum, pectin and starch may be used. Recently, a synthetic product, sodium carboxymethyl cellulose, has been introduced as a stabilizer.[156] Usually less than ½% of any of these stabilizers is added.

Overrun

Air is a necessary ingredient of ice cream, since without it the mix would freeze to a hard or soggy mass. The increase in volume secured by whipping air into the mix during the freezing process is known as *overrun.* The usual range of overrun is from 80 to 100%, but it may reach 150%. Thus, 1 gal. of mix makes about 2 gals. of finished ice cream and conversely, 2 gals. of ice cream melt down to about 1 gal. of liquid. Many states specify a minimum weight for a gallon of ice cream or require that it contains a certain minimum weight of food solids per gallon, in order to protect the consumer from a product that has an excessive overrun. An ice cream with an excessive amount of air lacks body and melts rapidly in the mouth.

An ice cream mix which attains the desired overrun rapidly is said to *whip* quickly. In a batch freezer, whipping is accomplished by shutting off the refrigerant as soon as the ice cream is frozen. The beater or dasher is allowed to revolve in order to incorporate the air in the ice cream. Whipping should be completed in 2 or 3 minutes in order to prevent the ice cream from melting from

lack of refrigeration. In the continuous freezer, whipping is accomplished automatically while the mix passes through the freezer.

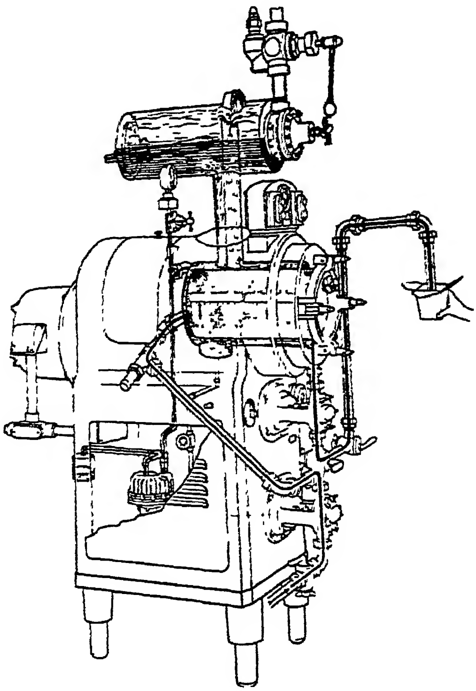


FIG. 64. *Diagram Showing Construction of Continuous Ice Cream Freezer*

The upper container holds liquid ammonia, which upon expansion within the insulated walls of the freezing unit, produces the low temperature needed to freeze the mix. Part of the dasher is shown within the freezing cylinder. In the rear, bottom portion of the machine, air is filtered, compressed and delivered to the freezing cylinder in regulated amounts. Mix enters the unit through the pipe on the front, bottom portion of the machine. *(Courtesy of The Creamery Package Mfg. Co.)*

Shrinkage

Since the overrun in ice cream is about 100%, it is to be expected that the product will lose air and decrease in volume in time. There are many reasons for such shrinkage, ranging from excessive original overrun to the effect of barometric pressure. The composition of the ice cream and the temperature at which it is stored also has its effect on shrinkage. Ice cream with

a high content of serum solids usually maintains its structure better and shows less shrinkage than a product of low solids content. Storage at a low temperature also favors retention of overrun, but if the temperature is too low, the ice cream may be too hard to serve immediately, as is done at fountains.

Air is forced out of ice cream when it is transferred from the original container to others, such as pint and quart cartons or to cones. It is not unusual for a 5-gallon container to show a total loss of 1 to 1½ gallons by the time it is dipped out in small lots. The sale of factory-filled quart and pint sized containers is much favored as this means minimizing shrinkage.

Varieties of Ice Cream

Plain Ice Cream

Any ice cream made with only a single flavor may be termed a plain ice cream. Usually the term refers to vanilla ice cream.

Fruit Ice Cream

This is ice cream made with the addition of fruit or fruit juice.

Nut Ice Cream

This is ice cream made with the addition of nut meats.

Parfait

An ice cream of high fat content and usually containing fruit, nuts and egg yolk, is called a parfait or sometimes is referred to as *New York* ice cream.

Mousse

This is a frozen confection made with whipped cream, sugar and flavor. An ice cream of very high fat content sometimes is also called a mousse.

Spumoni

Spumoni is a vanilla or chocolate ice cream of high fat content, and containing nuts and fruits.

Ice Cream Pudding

An ice cream pudding is a fruit ice cream made with an appreciable amount of egg or egg yolk.

Custard Ice Cream

Ice cream custard usually is the same as ice cream pudding. More correctly, it is a cooked mixture of milk and egg which is added to the ice cream mix and then frozen.

Ice Milk

This is a product similar to ice cream but it contains less milk fat, usually not much over 4.0%.

Sherbet

A sherbet is a frozen mixture of fruit juice and water to which sugar, cream, milk or ice cream mix has been added. In order to increase its tartness or acidity, about ½% or more of an organic acid, such as citric acid, usually is added.

Ice

An ice is a frozen mixture of fruit juice, water and sugar. It contains no milk constituent.

Composition of Ice Cream

As shown in Table 24, the composition of ice cream may vary considerably, especially in its fat and milk solids-not-fat content.

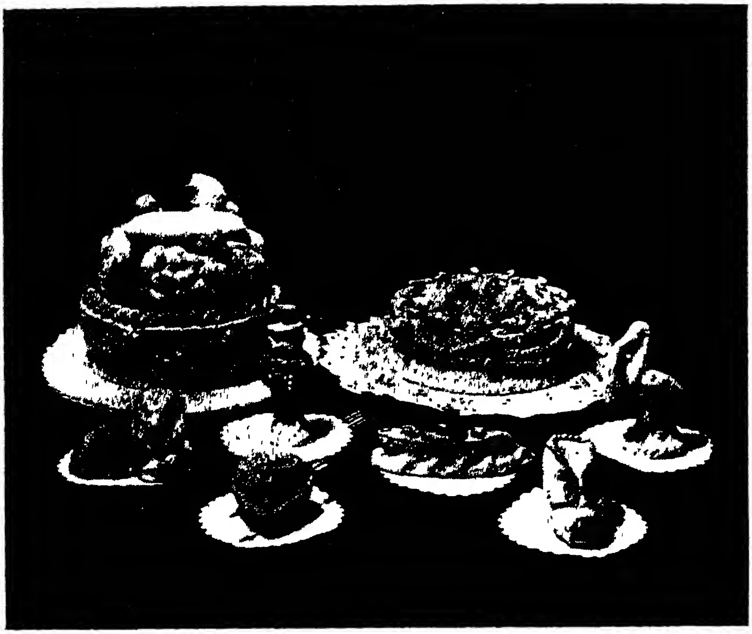


Fig. 65. *Fancy Ice Cream Molds*
(Courtesy of Golden State Co., Ltd.)

Table 24

Composition of Ice Cream

	Fat %	Milk Solids-Not-Fat %	Sugar %	Stabilizer %	Egg Yolk %
Maximum	25	14	18	1.0	4.5
Minimum	8	6	12	0.0	0.0
Usual Range	9–14	9–11	14–16	0.25–0.5	0.3–1.0

A number of proprietary compounds are sold for the preparation of ice cream at home. Most of these are mixtures of sugar, vegetable gum or gelatin, starch and flavoring materials which are to be added to milk and cream before freezing. Some preparations contain all the ingredients of ice cream except the water and so are actually a dry ice cream mix. Large amounts of these ice cream powders are used aboard ships or where it is not convenient to prepare or store the liquid mix. During World War II, a vast amount of ice cream powder was used by the armed forces

of the United States. A representative analysis of an ice cream powder is given in Table 25.

TABLE 25

Composition of Ice Cream Powder

Sugar %	Milk Solids-Not-Fat %	Milk Fat %	Stabilizer %	Moisture %
44	25	28	1	2

About 1 part of ice cream powder is mixed with 2 parts of water and the mixture is frozen in the usual manner. In order that a satisfactory overrun might be obtained, some ice cream powders contain an ingredient such as sodium caseinate, which increases the whipping properties of the mix.

Nutritive Value of Ice Cream

Ice cream is an excellent food and a concentrated source of energy, but because of its large amount of fat and carbohydrate it is an unbalanced food if made the principal part of a diet. Ice cream of average composition does not supply sufficient protein, mineral salts or vitamins to maintain normal growth as shown in experiments on animals. The addition of more dry milk solids-not-fat to the mix corrects this defect to a considerable degree.

It generally is agreed upon that ice cream is easily digested, especially since the homogenization and heat treatment of the mix favors the formation of a soft curd in the stomach. The flavor has a psychological effect and stimulates the flow of the digestive juice. The widespread use of ice cream in hospitals demonstrates the value placed upon it as a palatable, digestible and nutritive food. As it is cold it is acceptable to persons suffering from irritations and infections of the mouth or throat.

Ice cream of average composition furnishes about 1100 calories per quart or about 200 calories per serving. If it is assumed that the average overrun of ice cream is 100%, the calorific value of the frozen product is one-half that of the liquid mix from which it is made.

Bacteriology of Ice Cream

With the possible exception of a few flavoring materials, all of the ingredients used in the manufacture of ice cream contain harmless bacteria, often in very large numbers.

Flavoring extracts contain, as a rule, only a small number of bacteria, perhaps owing to the action of the alcohol or other solvents used in the extract. The bacteria in the ingredients are destroyed, to a large extent, when the ice cream mix is pasteurized. Bacteria and molds on nut meats may be destroyed by boiling the nuts in a thick syrup for about 15 seconds. Canned fruits are practically sterile if properly processed, but fresh and some frozen fruits may contain molds and yeasts as well as bacteria. Because of the whipping and mixing that occurs during freezing, the bacteria in the ice cream are evenly distributed throughout the product.

Long periods of storage or holding may permit the growth of some varieties of bacteria but they usually decrease in number during the hardening and holding periods. As a rule, the bacterial content increases when the frozen product softens and is refrozen, as sometimes happens in a storage cabinet.

In a very few cases, outbreaks of disease have been traced to the use of contaminated ice cream. Such unfortunate events can be avoided if all the ingredients of the ice cream are pasteurized and if care is taken to avoid subsequent contamination.

A number of states and cities have placed legal limits upon the maximum number of bacteria permitted in ice cream and other frozen dairy products. It is feasible to make ice cream with a bacterial content of less than 5000 bacteria per gram. Standards adopted by the various state and local authorities permit more bacteria, varying from 50,000 per gram upwards; some places having no standards at all.

CHAPTER 18

PRINCIPLES OF DAIRY TESTS; EXAMPLES IN DAIRY ARITHMETIC

Milk is one of the most valuable of all agricultural products, and it is important that the producer obtains full value for his products, and that the processor does not lose in the preparation or manufacture of milk products. For this reason accurate testing is an important part of dairy work (Fig. 66). Legal standards which define the sanitary quality as well as the nutritive value of milk products in terms of bacterial, fat and solids-not-fat content have been discussed in previous chapters. The principles of bacteriological examination have been discussed in Chapter 4.

FIG. 66. *Modern Dairy Laboratory*

Left: Mojonnier tester for making accurate fat and total solids tests. The operator is about to weigh a total solids test on the analytical balance. On far table, a microscope and to right, a viscosimeter used to measure thickness or body of ice cream mix. Rear right: Two Babcock centrifuges and rack for emptying Babcock test bottles. *(Courtesy of National Butter and Cheese Journal.)*

Sampling

An essential requirement for an accurate test is to obtain a sample that is representative of the material under consideration. Careful testing in itself will not make up for inaccuracies in sampling.

In the milk plant it is impossible to obtain a representative sample of the milk in a large vat or weigh-tank unless the milk is first thoroughly mixed, preferably by means of properly placed mechanical agitators.[159] Fresh milk from small containers should be sampled immediately after the milk has been thoroughly mixed with a suitable agitator or has been poured from one container to another several times.

When it is not practical to test each lot of milk *composite samples* may be taken. A composite sample is a mixture of single samples taken from different lots of milk or cream. They must be *representative of and in proportion to* the amount of product sampled. For example, if a dairyman delivers 50 pounds of milk one day, 100 pounds the next and 75 pounds the third day, the amount of milk in the sample from each shipment must be in proportion of its weight. Thus if one dipper of milk was taken as the sample for the first day's shipment, two dippers must be taken the next day and one and one-half dippersful for the third shipment. A further explanation of this reasoning is given in the section on dairy arithmetic for computing the weighted average of milk fat in different lots of milk.

If the milk in a composite sample is gathered over a period of time, it is necessary to preserve it lest it spoils before it is tested. This is done by adding to the milk a special preservative tablet containing mercuric chloride or by adding to each ounce of milk a drop or two of a solution of formaldehyde. Experience has shown that the most reliable fat tests are obtained with composite samples that have been preserved with formaldehyde and are not over two weeks old.

The Babcock Fat Test

The dairyman usually is paid for the milk he sells on the basis of its fat content. Sometimes an allowance is made for its solids-

not-fat, especially if the milk is to be used in the manufacture of cheese or dry milk.[137, 27] The Babcock fat test generally is used in creameries in the United States for the determination of the fat content of milk and cream. Probably no other single chemical test of any kind is used so extensively to place a value upon a commodity. A constant error of as little as 0.1%, one way or the other, in the results of the fat test would mean a loss of millions of dollars to the milk producers of the nation or to the creamery operators.

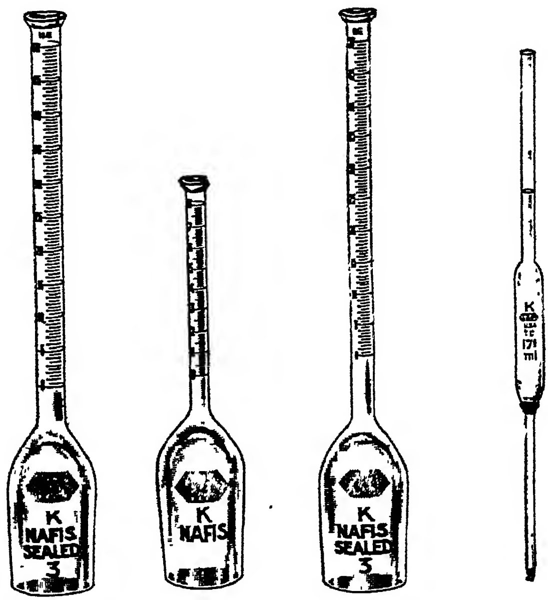


FIG. 67. *Babcock Test Glassware*

1. Cream Test Bottle, for 18 grams of cream (1/3 actual size).
2. Milk Test Bottle (1/3 actual size).
3. Cream Test Bottle, for 9 grams of cream (1/3 actual size).
4. Milk Pipette (1/5 actual size).

The Babcock test was developed about sixty years ago by Professor S. M. Babcock of the University of Wisconsin. The procedure is the following:

Place 17.5 milliliters of sample in a Babcock milk test bottle by means of a Babcock pipette (Fig. 67). Insert the pipette in the neck of the bottle, allow the milk to drain into the bulb of the bottle and remove the final drop by blowing into the pipette. Add

17.5 milliliter of sulfuric acid (specific gravity 1.82–1.83). Mix the acid and milk by a rotary motion until all traces of undissolved curd have disappeared. Hold the bottle with its neck away from the operator in order to avoid any accidental spatter of acid. Place the test bottles in the centrifuge, taking care that the load is properly balanced. The centrifuge should be heated to 140°F. The correct speed of the centrifuge depends upon its diameter, measured with the carrier cups horizontally extended. The correct speed is as follows:

Diameter of wheel, inches—	14	16	18	20	22	24
No. revolutions per minute—	909	848	800	759	724	693

Whirl the test bottles for 5 minutes, then add sufficient hot water (140°F. or over) to fill the bulb of the bottle. Whirl another 2 minutes and then add hot water until the fat column approaches the top graduation on the bottle. Whirl one minute more. Transfer the bottle to a water bath maintained at 130–140°F. for at least 10 minutes. The water level in the bath should reach to the top of the fat column.

Measure the percentage of fat with a pair of sharp pointed dividers, holding the bottle so that the fat column is at eye level. Place one point of the dividers at the extreme bottom of the fat column, the other at the top of the meniscus. The *meniscus* is the crescent-shaped portion on top of the fat column and is caused by the attraction of the fat and the glass, the fat rising higher where it touches the glass than in the center of the column where there is no such attraction. Then without changing the spread of the dividers, place the lower point on the 0 graduation mark on the bottle; the other point then indicates the percentage of fat in the sample.

Since milk has an average specific gravity of 1.03, the sample delivered by the milk test pipette weighs 17.5 × 1.03 or 18 grams. The neck of the test bottle is so calibrated that each whole percent represents a volume of 0.2 milliliter. The capacity of the neck of a milk test bottle graduated from 0 to 8% is 1.6 milliliters. The melted fat obtained in the test has a specific gravity of 0.9. A milk sample that contains 4% of fat yields 18 × 0.04 or 0.72 gram of fat. This fat occupies 0.72 ÷ 0.9 or 0.8 milliliter. Since each per cent of graduated neck of the test bottle occupies 0.2 milliliter,

a fat column occuping 0.8 milliliter represents 0.8 ÷ 0.2 or 4% of fat in the milk sample.

A trace of fat is destroyed in the test and some of the fat globules in the milk are so small that they do not rise into the neck of the test bottle. In order to obtain an accurate test on milk, this loss is compensated for by reading the fat column from its lowest point to the extreme top of the meniscus. The fat column should be read in a diffused or indirect light, such as is obtained from a north window. By proper adjustment of the light or by seeking the proper place in the room from where to make the reading, the top of the meniscus is easy to see. It will then appear like the top of a letter *D* lying on its side, the top of the meniscus itself appearing as a straight, dark line.

Some lots of acid of the proper specific gravity may not give a satisfactory test. In such cases, dilute the acid with sufficient water so that a fat test is obtained in which the fat column is translucent golden yellow or amber in color, free from charred matter or other visible particles. (Note: In diluting the acid, add the acid to the water, never water to acid.)

At the time of testing, the prepared milk sample should be at a temperature between 60° and 70°F. and the temperature of the acid should not exceed 70°F.

Dark colored fat columns or those that contain charred matter are caused by (1) too strong acid, (2) too much acid, (3) milk or acid too warm when mixed, (4) allowing the milk and acid to stand in the bottle before mixing, or (5) by improper or inadequate shaking to mix the milk and acid.

Pale colored fat columns, often underlaid with white sediment are caused by (1) weak acid, (2) too little acid, (3) acid or milk too cold or (4) insufficient mixing. It is well to adjust the amount of acid added to the milk according to the type of fat column obtained. Formaldehyde has a hardening action on the curd of milk, and milk so preserved must be mixed with the acid for at least three minutes in order to insure complete dissolution.

Homogenized milk may be tested in the same manner as ordinary milk, except that the sample is mixed for at least 5 minutes after adding the acid.[190]

Skim milk and buttermilk may be tested by the Babcock method,

provided a special test bottle is used. Owing to the small amount of fat in these products, this test bottle has a very small graduated neck in which the fat is measured.

A modification of the test, known as the *butyl alcohol test* is used for buttermilk For this test place 2 milliliters of butyl alcohol in a Babcock test skim milk bottle, add 9 milliliters of buttermilk and then add 7 milliliters of Babcock test sulfuric acid. Mix thoroughly, centrifuge for 6 minutes and complete the test as for the Babcock test for milk. Double the fat reading to obtain the percentage of fat.

Since cream varies in thickness, it cannot be measured satisfactorily by volume as is done with milk. Cream is weighed into the test bottle, using either 9 or 18 grams of sample, depending upon the size of test bottle used. The cream test bottle has a larger neck than the milk test bottle because of the higher fat content of cream. Otherwise, cream is tested practically by the same procedure used for milk. Less acid is needed in the test, because of the lower solids-not-fat content in cream. A small amount of water is added to the test bottle, in order to wash down any cream adhering to the inside of the neck of the bottle, as well as to dilute the acid used for the test. Enough acid is used to give the mixture of cream and acid a chocolate-brown color.

Experience has shown that all of the fat in cream appears in the fat column and in order to obtain an accurate test, the meniscus must not be included in the reading. In a cream test, the meniscus is destroyed, just before reading the fat column, by allowing a small amount of colored mineral oil, also called *glymol,* to run down the neck of the bottle and to rest on top of the fat column. This levels off the meniscus, the reading being taken at the dividing line between the milk fat and the added mineral oil (Fig. 68).

The Gerber or Fucoma Fat Test

This test, devised by the Swiss chemist N. Gerber, is used in Europe and to some extent in this country. Like the Babcock test, it makes use of chemicals and a centrifuge to separate the fat from the sample. In addition to sulfuric acid, amyl alcohol is used to hasten the action of the acid and to prevent the formation of charred matter which may occur with acid alone. Special test

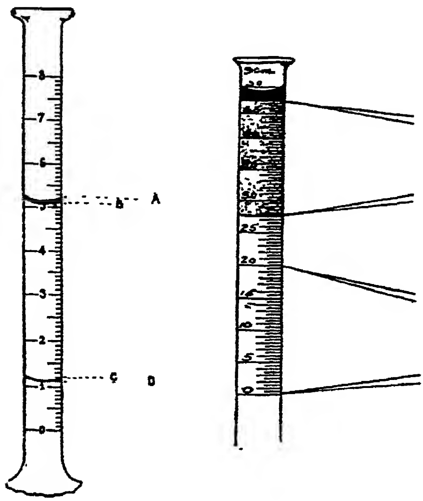


FIG. 68. *Reading the Babcock Test*

Left: Milk Test. The meniscus is the dark line between A and B. The test is read by measuring the height of the fat column A to D with a pair of dividers: without changing the setting of the dividers, the lower arm is placed against the zero point on the graduated neck. The upper arm then points to the percentage of fat in the sample, as indicated in the figure to the right.

Right: Cream Test. Colored mineral oil (glymol) is added to the fat column to destroy the meniscus.

bottles, called butyrometers, are used as well as special pipettes and equipment for adding the acid and alcohol to the test bottles (Fig. 69). A special centrifuge is used, which unlike that used for the Babcock test, need not be heated in order to obtain an accurate test. The Gerber test is probably somewhat quicker than the Babcock test and, when conducted with care, is capable of an equal degree of accuracy. Either test gives results with milk that average within 0.04% of those obtained by ether extraction of the fat.

The procedure for the Gerber test for fat in milk is as follows:

1. Place 10 milliliters sulfuric acid (Babcock test grade) in the butyrometer.
2. Measure, with the special pipette, 11 milliliters of milk into the butyrometer, allowing it to run down the side of the bottle, forming a layer above the acid.
3. Add 1 milliliter of amyl alcohol.

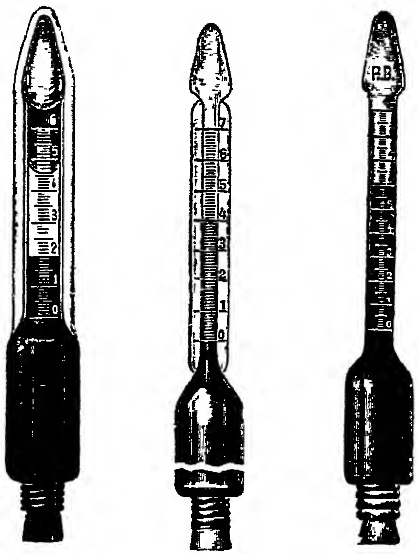


FIG. 69. *Butyrometers Used for the Gerber Fat Test*

4. Insert the stopper and thoroughly mix until the curd is dissolved.
5. Place the bottles in the centrifuge with the neck toward the center.
6. Centrifuge 3 to 5 minutes at 1000 revolutions per minute.
7. Remove the bottles from the centrifuge and place for 5 minutes in a water bath heated to 140°F.
8. Read the fat percentage by substracting the reading of the lower flat portion of the fat column from the *bottom* of the upper meniscus.

By raising or lowering the rubber stopper in the butyrometer, the fat column can be brought to a position to facilitate the reading.

By using special butyrometers and making modifications in the procedure, the Gerber test may be used for the estimation of fat in cream, skim milk, buttermilk, ice cream, butter and cheese.

Ether Extraction (Mojonnier Method)

The Babcock fat test is not sufficiently accurate for the exact analysis of evaporated milk, ice cream, cheese and dry milk, even

though it does give acceptable results for milk and cream. An exact fat determination is a chemical procedure which demands an ether extraction of the fat. The Mojonnier test is a widely used mechanical adaptation of the classical Roese-Gottlieb ether extraction procedure (Fig. 66).[191]

An accurately weighed sample is dissolved in water. Ammonia is added to dissolve the milk proteins and then alcohol is added to prevent the formation of a thick emulsion, which might occur when the mixture is shaken. The fat is extracted from the solution by shaking with ethyl ether. This ether dissolves a small amount of the aqueous solution also and therefore contains a small amount of non-fat material, such as milk sugar. In order to remove these materials from the ethyl ether an equal amount of petroleum ether is added. The ether mixture, being lighter than the other liquids present, rises to the top of the mixture, carrying the fat in solution. The ether layer is transferred to an accurately weighed aluminum dish which is placed on an electric hot plate to remove the ethers by evaporation. Provision is made to remove the vapors by means of a suction fan. The extracted fat remains in the dish which is dried in a vacuum oven and then is cooled in a desiccator. From the weight of the fat in the dish, the percentage of fat in the sample may be calculated.

Total Solids and Solids-not-Fat

The approximate total solids or the solids-not-fat content of milk may be determined from its fat content and specific gravity. The specific gravity may be determined by means of a lactometer, which is a special form of hydrometer designed for use with milk. The *Quevenne* type lactometer is the most acceptable one, although the New York Board of Health lactometer is used to a limited degree in and around New York. The Board of Health lactometer reading is converted to the Quevenne by dividing the Board of Health reading by 0.29.

The reading obtained with the Quevenne lactometer is not an actual specific gravity reading. The ordinary lactometer has a scale graduated from 15 to 40, corresponding to specific gravities from 1.015 to 1.040. The best form of instrument has a large bulb and a narrow graduated neck. For routine use, a lactometer provided with a thermometer is convenient.

The lactometer reading is correct only when taken at a temperature of 60°F. and corrections must be applied if the reading is made at some other temperature. On the average, the reading increases 0.1 lactometer degree for each degree of temperature below 60°F. and decreases a like amount for each degree above 60°F.

To take a lactometer reading, place the well mixed milk sample in a cylinder or container large enough to float the lactometer and having a diameter greater than that of the bulb of the lactometer. The container should be filled so that it will overflow when the lactometer is placed in it. Let the lactometer float freely and after ½ minute take the reading. Any bubbles on the surface of the milk should be blown off before taking a lactometer reading. The scale is read at the highest point reached by the milk meniscus around the lactometer stem, not at the principal surface of the milk.[192]

By means of a formula based upon the fat content and the lactometer reading, the total solids or the solids-not-fat in a sample of milk may be easily calculated. The Babcock formulas for this purpose are:

$$\text{Solids-not-fat} = \frac{\text{Fat\%}}{5} + \frac{\text{Corrected lactometer reading}}{4}$$

$$\text{Total Solids} = 1.2\ \text{Fat\%} + \frac{\text{Corrected lactometer reading}}{4}$$

Tables and slide rules for this calculation have also been constructed.

The author's nomograph, shown in reduced form in Figure 70, gives temperature corrections, as well as total solids and solids-not-fat for milk of a given lactometer reading and fat content.[193] If the lactometer reading is made at a temperature other than 60°C., a straight line on the chart connecting the temperature with the observed lactometer reading will pass through the corrected lactometer scale at a point indicating the corrected reading. If this point is then connected by a straight line with the fat content of the sample, as shown on the percent fat scale, the line will pass through a point on the appropriate scales showing the percent solids-not-fat and total solids in the sample. For routine use of the chart, a transparent plastic straight edge is most convenient.

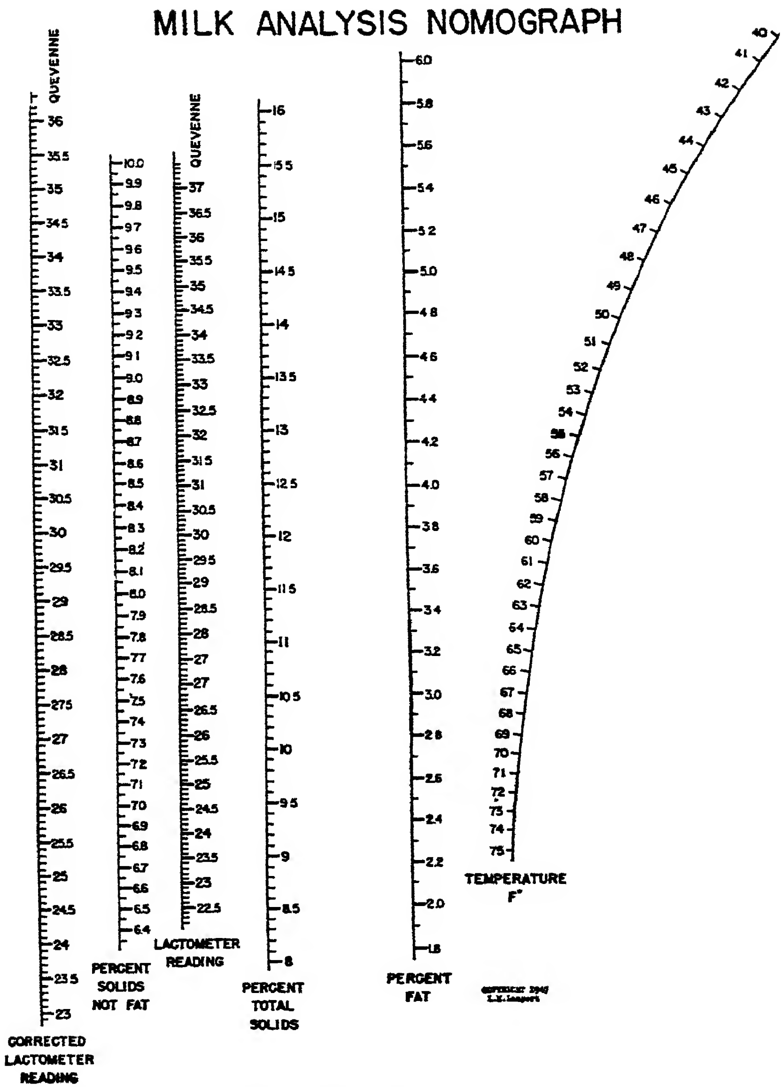


FIG. 70. *Milk Analysis Nomograph*

The lactometer is used as an aid in detecting milk to which water might have been added. Normal milk rarely has a specific gravity less than 1.030 (lactometer reading of 30) and therefore a lower lactometer reading would justify suspicion that the milk had been adulterated. A more accurate test, such as the freezing point

or cryoscope test should be used to confirm the presence of added water.

Total solids in milk products may be determined by weighing a small sample of the product in an aluminum dish of known weight. The dish then is heated upon a steam bath or hot plate until most of the moisture in the sample has evaporated. The dish then is placed in a vacuum oven, at 100–105° C. for the final drying. After cooling, it is again weighed and from the loss of weight the amount of water evaporated is calculated. By subtracting the weight of water from the original weight of the sample, the amount of dry matter or total solids is obtained.

Acidity

Fresh milk or cream does not contain any appreciable amount of lactic acid and therefore an increase in its acidity is a rough measure of its age and bacterial activity. In sour milk, the acidity usually is more than 0.3%, expressed as lactic acid. This acidity is determined by titration, that is, the acid is exactly neutralized by the addition of a measured amount of standard alkali solution, usually 0.1 normal sodium hydroxide solution. Each milliliter of 0.1 normal alkali will neutralize 0.009 gram of lactic acid. When 9 grams of milk are titrated, each ml. of 0.1 normal alkali used is equivalent to 0.1% of lactic acid. A 1% alcohol solution of phenolphthalein is used as the indicator for the titration. Phenolphthalein is colorless in acid solution and pink in the presence of alkali. A few drops of the indicator are added to the sample and the standard alkali solution is added gradually from a burette. As soon as the acid present is neutralized, the first drop of excess alkali solution added acts upon the indicator and turns it pink, thus indicating that the end point has been reached and all of the acid has been neutralized. The percentage of acidity may be found by means of the formula:

$$\%\ \text{acidity} = \frac{\text{ml. 0.1 normal alkali} \times 0.009}{\text{weight of sample}} \times 100$$

It is customary to add distilled water to evaporated milk and other concentrated milk products in order to dilute them to a fluid milk basis before titrating for acidity. If milk is diluted

with water before titrating, a lower acidity is obtained since the water causes a change in the milk salts with a decrease in their acidity.

Hydrogen-Ion Concentration or pH

When fresh milk is titrated with a standard solution of alkali, its acidity is equivalent to 0.13 to 0.18% lactic acid. Since fresh milk contains no lactic acid, this acidity is an apparent acidity and is a measure of the amount of alkali that combines with the protein and mineral salts in the milk. Fresh milk of high normal total solids content will show a higher titratable acidity than fresh milk of low total solids content. When bacterial fermentation takes place, lactic acid is formed and the acidity of the milk is increased.

The acidity of acids is due to the hydrogen ions. Alkalies or basic substances are characterized by the presence of hydroxyl ions. Both hydrogen ions, expressed by (H) and hydroxyl ions (OH) are present in water. This is seen clearly if the chemical formula of water is written H.OH instead of H_2O. In pure water as many hydrogen or acid ions are present as OH or alkali ions. Water therefore is neither acid nor alkaline, but is neutral. Actually it is very difficult to prepare water so pure that it is exactly neutral, because many substances, especially the carbon dioxide of the air, are readily dissolved in it.

For technical reasons, chemists state that a solution in which the acid ions are equal in number to the basic or alkaline ions, has a pH of 7 and is neutral in reaction. The term pH is pronounced by naming each letter separately p—h. Different numerical values indicate different degrees of acidity or alkalinity, much as the numbers on a thermometer scale indicate degrees of temperature. A pH of less than 7 indicates acidity, a number greater than 7 indicates alkalinity. The pH numbers represent logarithmic values and each whole number in the scale means an increase or decrease in the number of hydrogen ions by ten. Thus a pH of 2 means ten times the number of hydrogen ions as at pH 3 and 100 times as many as at pH 4. A similar relationship holds true for the alkaline side; pH 8 means ten times as many hydroxyl ions as at pH 7 and pH 10 indicates 100 times the hydroxyl ion concentration as at pH 8.

The approximate pH values of some substances is given in Table 26.

TABLE 26

Approximate pH Value of Some Food on Other Products

Blood	7.3–7.5	Lemon Juice	2.2–2.4
Bread, White	5.0–6.0	Milk, Cow's	6.5–6.8
Cheese, Cheddar	5.6–6.0	Milk, Evaporated	5.9–6.2
Cheese, Process	5.7–6.2	Milk, Human	6.8–7.2
Cheese, Roquefort	4.8	Sauerkraut	3.5
Cheese, Swiss	5.7–5.9	Water, Distilled	5.8
Cider	2.9–3.3	Water, Purified	6.8–7.0

In general, two methods are used to measure the pH value of a solution. Very accurate measurements can be made with electrical apparatus or by colorimetric determinations with indicator solutions. Various indicators, which change color at different pH values, are available. The color obtained is compared with a standard color to determine the pH of the solution.[203]

Buffers

Certain substances, known as *buffers* have the property of resisting a change of pH in their solutions, that is, they tend to maintain a constant pH. Among these materials are soluble borates, acetates, phosphates and citrates. The phosphates and other mineral salts in milk act as buffers. The pH of milk is about 6.6, being only very slightly acid. When bacterial activity results in the formation of lactic acid in milk, the pH does not change rapidly because of the buffers acting in the milk. The acid may increase in amount until a break in buffer action occurs, at which point the pH of the milk drops to about 4.5 and it curdles. An acid, such as acetic acid or sulfuric acid may be added to milk until a pH of about 4.5 is reached before curdling occurs.

Sediment Test

As mentioned in Chapter 6, the presence of foreign matter in milk is objectionable not only on account of the dirt itself but also because it indicates carelessness during processing. Visible dirt

also indicates the probability that other foreign matter has gone into solution in the milk.

When bottled milk is allowed to stand undisturbed for a length of time, insoluble extraneous matter will, in general, sink to the bottom and become visible when the milk is examined through the bottom of the bottle.

Special equipment is used by inspection services to examine milk or cream for the presence of sediment. A pint sample is forced by air pressure or vacuum, through a cotton filter disc. The sediment is collected on the disc which is then removed for observation (Fig. 71).

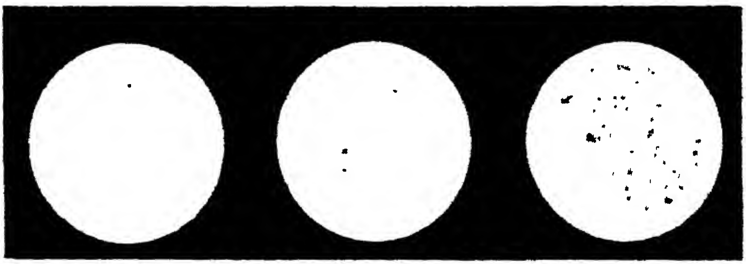


FIG. 71.

Sediment discs obtained from (1) clean, (2) passable, (3) dirty cream. *(Courtesy of American Butter Institute.)*

Testing of Butter

Butter is tested for its fat, moisture and salt content. Ten grams of a well mixed sample is placed in a small, aluminum dish of known weight, which then is treated as follows:

1. Moisture

Heat the sample on a hot plate or over a flame until the water is evaporated. Cool, reweigh and calculate the moisture content. Since a 10-gram sample is used, the loss in weight times 10 gives the percent of moisture in the sample.

As a rule, the water is evaporated when the melted fat has acquired an amber color and the salt and curd have collected on the bottom of the dish. Very few, if any, bubbles should be present on the surface of the melted fat.

2. Fat

To the dry residue in the dish, add light gasoline or petroleum

ether. Stir thoroughly to dissolve the fat, then allow the salt and curd to settle. Decant the solution, taking care that none of the residue is lost. Repeat the extraction 3 times in all. Dry the residue, preferably on a hot plate, taking care that none of the curd is lost by spattering. Cool and reweigh. The difference between this weight and the previous one represents the fat in the sample. Multiply by 10 to obtain the percentage.

3. Salt

Dissolve the residue in distilled water, making the total volume 250 milliliters. Titrate 25 milliliters with a standard silver nitrate solution, using potassium chromate as indicator.

4. Curd

Curd represents the non-fat milk solids present in butter. It is determined by substracting the percentage of moisture, fat and salt from 100.

Phosphatase Test

The phosphatase test is very important in milk control work.[194] It is used to determine whether or not a sample of milk, cream or cheese had been pasteurized properly. Raw milk contains an enzyme, phosphatase, which in the presence of alkali can decompose certain organic compounds of phosphoric acid. The compound used in the test is disodium phenyl phosphate, a combination of phenol and phosphoric acid. This preparation does not contain any free or uncombined phenol, but when acted upon by the phosphatase, it is split into its components and phenol is liberated. Extremely small amounts of phenol may be detected by chemical means. The commonly used reagent is *B.Q.C.* solution (a 0.4% alcoholic solution of 2,6, dibromoquinonechloroimine), which gives a deep blue color with phenol.

When milk is pasteurized, practically all of the phosphatase is destroyed and the milk is unable to act upon the phenol-phosphoric acid compound added to it. As a result, properly pasteurized milk gives little or no color in the test. If the milk is underheated or contains as little as 0.1% raw milk, enough phosphatase is present to liberate phenol and to yield a blue color indicative of improperly pasteurized milk. The phosphatase test is of great value for the public health since milk heated sufficiently to destroy the phosphatase enzyme has been heated also suffici-

ently to destroy any pathogenic organisms that may have been present.[80]

Compact units, containing the equipment and reagents for making routine phosphatase tests are available commercially.

Since the enzyme is associated with the fat portion of milk, cream should be diluted with distilled water or boiled milk to about 4 or 5% fat content before it is tested. Such dilution enables the operator to use the same standards as for testing milk. A modified test can be applied to cheese.[illegible]

Test for Added Water

A simple test is used by inspection and control laboratories to detect and measure added water in milk. A large amount of added water can be detected by use of the lactometer, but this instrument is not sufficienly accurate for control use. The most accurate means of detecting added water is to measure the freezing point of the milk sample.

Many investigators have shown that milk has a fairly constant freezing point, varying but a few thousands of a degree between different samples of pure milk.[139] The freezing point is independent of the variation in composition of milk as it comes from the cow. Neither the breed of cow nor her feed have any effect upon the freezing point of the milk.

Pure water, as is well known, freezes at 0°C. (32°F.) and pure milk freezes at about —0.55°C. (31°F.). If water is added to milk, the freezing point of the mixture rises. The more water is added, the more closely does the milk's freezing point approach that of pure water. The temperature is measured with a very sensitive thermometer which can be read to 0.001°C. Under carefully controlled conditions, the presence of 0.1% added water may be detected in milk. The apparatus commonly used for this test is known as the Hortvet cryoscope.[25]

Some Examples in Dairy Arithmetic

A number of problems which require the application of arithmetic frequently confront the dairyman and milk processor. Some of these are of sufficiently wide interest to be mentioned here; others, such as the calculations needed in the manufacture of ice

cream mix. are too involved to be considered here and information on them should be obtained from special books.[200]

Calculation of the Average Fat Percentage

The average percentage of fat contained in two or more lots of milk, cream or other milk products is obtained by multiplying the number of pounds of each product by its corresponding percent of fat in order to obtain the total weight of fat. The weight of fat divided by the total weight of milk or cream, multiplied by 100 gives the average percent of fat in the entire lot.

Example:

Find the average percent fat contained in 40 gallons of milk testing 3.5% fat, 70 gallons of cream of 30% fat content and 15 gallons of milk of 3.8% fat content.

Adding the individual fat percentages and dividing by three gives a fallacious result since the weight of the individual lots of milk and cream is not taken into consideration.

Solution:

First determine the weight of each lot. Table 36 shows that 1 gallon of milk weighs 8.6 pounds, and 1 gallon of cream containing 30% of fat weighs 8.4 pounds.

40 x 8.6 = 344 pounds of 3.5% milk.
70 x 8.4 = 588 pounds of 30% cream.
15 x 8.6 = 129 pounds of 3.8% milk.

1061 pounds—total weight of milk and cream.

344 x 0.035 = 12.040 pounds fat in the 3.5% milk.
588 x 0.30 = 176.400 pounds fat in the 30% cream.
129 x 0.038 = 4.902 pounds fat in the 3.8% milk.

193.342 pounds fat in the entire lot.

$$\frac{193.342}{1061} \times 100 = 18.22\%$$ fat in the entire lot of milk and cream mix.

Determining the Price of Milk

Milk generally is sold by the producer on the basis of its fat content rather than by the gallon. As a rule, the price is fixed on

the basis of 100 pounds of milk of a given fat content. A certain sum per 100 pounds of milk is added to the price when the milk tests above the standard fat content and a proportionate amount is deducted for milk testing below the standard. For example, in a certain area milk was sold for $2.30 per 100 pounds of milk containing 4% of fat. Milk testing above 4% fat commanded a premium of $0.05 for each 0.1% above 4.0% and a like amount was deducted for each point or 0.1% below 4%.

Problem—How much did a producer in the above market receive for 100 pounds of milk testing 3.7% fat content?

Since the milk tested three points below the standard, the price paid was

2.30 — (3× 0.05) or $2.15 per 100 pounds.

Although most milk producers are paid on the basis of the fat content of the milk sold, such payment does not give adequate consideration to the solids-not-fat in the milk, nor to the relative values of milk of high and low fat content. Milk of high fat content is relatively low in solids-not-fat and does not yield as much cheese, dry milk or evaporated milk as does milk naturally low in fat.

Various schemes have been devised in an effort to pay producers a price commensurate with both the fat and the solids-not-fat in milk. Creameries, cheese factories, milk drying and evaporated milk plants often use formulas to establish the price paid for the milk used. The formulas are based upon the current wholesale prices of butter, cheese and milk powder.[195, 207]

Standardizing Milk and Cream

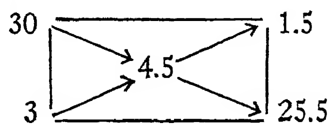
In order that a milk product should have a uniform fat content it generally is necessary to adjust the percentage of fat to a definite amount, this process being known as *standardization*. The calculation involved is to determine the amount of cream that must be added to increase the fat content of the material being standardized or the amount of skim milk to add if the fat content is too high. A simple method, devised by Prof. R. A. Pearson of Cornell University, and known as the *Pearson square* is used in the computation. The procedure is as follows:

Draw a square or rectangle and place in its center the percentage of milk fat desired. At the left-hand corners place the

percentages of milk fat in the materials to be mixed. From the larger number on the left-hand side, subtract the number in the center. Place the remainder on the right-hand side of the square and at the corner diagonally opposite from the number used on the left-hand side. Next subtract the smaller number on the left-hand corner from the number in the center, and place the remainder on the diagonally opposite corner on the right-hand side of the square. The figure on the upper right-hand corner refers to the product represented by the figure on the upper left-hand corner of the square and the figure on the lower right-hand corner refers to the product represented by the figure on the lower left-hand corner. Examples will make the use of the Pearson square clear.

EXAMPLE:

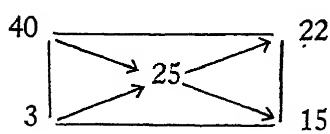
How much 30% cream must be mixed with 3% milk to prepare milk testing 4.5%?



This means that 1.5 pounds of 30% cream must be mixed with 25.5 pounds of 3% milk to yield milk testing 4.5% fat. The figures on the right hand side give the proportions to be used and so any multiple of them can be used; for example, 3 pounds of cream and 51 pounds of milk, to make a total of 54 pounds of 4.5% milk.

EXAMPLE:

500 pounds of 40% cream is to be reduced to 25% fat content. How much milk of 3% fat content must be added?



According to the diagram, 22 pounds of 40% cream is needed for every 15 pounds of 3% milk in order that the mixture contains 25% milk fat. This mixture would weigh 37 pounds, but according to the problem, 500 pounds is needed. In order to obtain a 500 pound mixture it is necessary to multiply both the

22 and 15 by the number of times their sum, 37, is contained in 500, that is by 500/37 or 13.513

$$22 \times 13.513 = 297.286$$
$$15 \times 13.513 = 202.695$$

The above result shows that 297.3 pounds of 40% cream must be mixed with 202.7 pounds of 3% milk in order that 500 pounds of 25% cream be obtained.

TABLES 27–41

TABLE 27

Milk Equivalents

The amount of milk, containing 3.5% fat, which is required to prepare 1 pound of a milk product is approximately as follows:

Product	Pounds of Milk Required	Product	Pounds of Milk Required
Butter	23	Ice Cream (per gallon)	14
Cheddar Cheese	10	Dry Milk	7.8
Evaporated Milk	2.5	Dry Cream	19
Sweetened Condensed Milk	2.5	Malted Milk	2.3

TABLE 28

Principal Constituents of Milk

Water		87.29%
Fat [1]		3.66%

[1] The principal fatty acids are listed in Table 29.

Lecithin		0.03 %
Cholesterol		0.015%
Lactose		4.92 %
Glucose		0.15 %
Proteins [2]		3.42 %
Casein	2.85%	
Lactalbumin	0.52%	
Lactoglobulin	0.05%	

[2] The principal amino acids found in the milk proteins are given in Table 32.

Minerals [3]	0.09%

[3] The principal mineral constituents are given in Table 2.

Citric Acid	0.17%

Vitamins

At least 15 vitamins have been found in milk. See Table 5.

Enzymes

Amylase, Catalase, Lipase, Peroxidase, Phosphatase, Protease, Reductase and others.

Traces of more than 40 substances, other than those referred to above have been reported present in milk.

TABLE 29

Fatty Acids Found in Milk Fat of Different Animals and Human Milk

Fatty Acid	Percentages by Weight Cow	Ewe	Goat	Mare	Human
Butyric[1]	3.0– 3.7	3.0	2.8	0.4	
Caproic[1]	1.4– 2.0	2.5	2.6	0.9	
Caprylic[1]	1.0– 1.5	2.8	2.2	2.6	
Capric[1]	2.7– 2.6	2.8	2.2	2.6	
Lauric	1.7– 3.7	6.0	5.9	5.6	0.5– 2.7
Myristic	9.3–12.1	12.3	9.7	7.0	7.6–13.9
Palmitic	25.3–25.4	27.9	23.9	16.1	22.4–24.6
Stearic	9.2–10.7	6.0	12.6	2.9	7.3– 9.6
Oleic[1]	29.6–32.4	21.1	26.3	18.7	30.2–36.6

[1] These fatty acids are liquid at body temperature.

The above table is based upon data by: T. P. Hilditch and M. C. Meara, Biochem. J. 38, 25–34, 437–442 (1944); T. P. Hilditch and Jasperson ibid. 38, 443–447 (1944). T. P. Hilditch, *The Chemical Constitution of Natural Fats*, New York, J. Wiley and Sons, 1941.

TABLE 30

Amino Acids Essential to Nutrition

See also Tables 31 and 32

Lysine	Isoleucine
Tryptophane	Threonine
Histidine	Methionine
Phenylalanine	Valine
Leucine	Arginine

Dispensable Amino Acids *

Glycine	Hydroxyglutamic Acid
Alanine	Proline
Serine	Hydroxyproline
Norleucine	Citrulline
Aspartic Acid	Tyrosine
Glutamic Acid	Cystine

W. C. Rose, W. J. Haines and J. E. Johnson: The Role of the Amino Acids in Human Nutrition, *J. Biol. Chem.*, **146**, 683 (1942).

W. C. Rose, W. J. Haines, J. E. Johnson and D. T. Warner: Further Experiments on the Role of Amino Acids in Human Nutrition, *J. Biol. Chem.*, **148**, 457 (1943).

W. C. Rose, The Nutritive Significance of the Amino Acids: *Physiol. Rev.*, **18**, 109 (1938).

* Dispensable amino acids can be synthesized by the body if not supplied in the diet.

Table 31

Daily Requirements of Essential Amino Acids

Estimated Amounts. Sources of Supply [202]

Amino Acid	Estimated Daily Requirement gm	Supplied by 100 Grams of Protein from Meat gm.	Milk gm.	White Flour gm.	"Enriched" Bread gm.
Arginine	3.6	7.2	4.3	3.9	3.5
Histidine	2.0	2.1	2.5	2.2	2.3
Lysine	5.2	8.1	7.5	2.0	2.8
Tyrosine	3.9	3.1	5.4	3.8	4.4
Tryptophane	1.1	1.2	1.6	1.0	1.3
Phenylalanine	4.5	4.5	5.7	5.5	5.1
Cystine and Methionine	3.8	4.2	4.0	4.2	4.2
Threonine	3.4	4.3	4.6	2.7	2.8
Leucine	9.0	12.1	16.2	12.0	11.2
Isoleucine	3.3	3.4	4.4	3.7	3.3
Valine	3.8	3.4	5.5		3.1

Table 32

Amino Acids in Human and Cow Milk Proteins [202]

Amino Acid	Cow Casein %	Human Casein %	Cow Lactalbumin %	Human Lactalbumin %
Arginine	3.9	3.4	3.6	5.0
Histidine	2.0	2.0	1.4	1.5
Lysine	6.0	5.6	6.2	6.6
Tyrosine	5.5	5.5	3.5	4.5
Tryptophane	1.3	1.5	2.1	2.3
Phenylalanine	5.5	5.8	4.5	4.8
Cystine	0.4	0.6	3.1	3.8
Methionine	3.1	2.3	2.4	1.7
Threonine	4.6	4.5	4.3	4.0
Leucine	14.4	12.2	17.4	16.7
Isoleucine	5.2	6.3	4.2	4.3
Valine	5.3	5.0	4.0	4.1
Alanine	2.3	2.0	2.6	2.3
Glycine	0.4	0.0	0.0	0.0
Proline	8.1	8.9	4.0	3.5
Aspartic Acid	4.2	4.6	9.6	9.3
Serine	5.0	5.4	4.0	4.2
Glutamic Acid	21.9	20.9	13.7	12.5

TABLE 33

Percentage of Optimal Daily Requirement of Each of the Essential Amino Acids Supplied by 100 Grams of Protein from Meat, Milk, White Flour, Vitamin-Enriched Bread, Corn, and Soybeans[201]

Amino Acid	Average Requirements Calculated	Supplied by 100 Grams of Protein from Meat	Milk	White Flour	Enriched Bread[a]	Corn	Soybeans
	g.	%	%	%	%	%	%
Arginine	3.5	210	125	110	110	115	165
Histidine	2.0	105	125	110	113	120	115
Lysine	5.2	145	140	40	55	40	105
Tyrosine	3.9	80	140	100	115	155	105
Tryptophane	1.1	110	175	90	120	55	145
Phenylalanine	4 4	100	130	125	115	105	125
Cystine and Methionine	3.8	110	105	110	110	130	80
Threonine	3.5	125	135	80	80	105	120
Leucine	9.1	135	180	130	120	240	90
Isoleucine	3.3	105	135	110	100	115	125
Valine	3.8	90	145	...	80	120	115

The figures in this table show that proteins of animal origin are somewhat superior to those of vegetable origin. Meat, for example, supplies about twice the amount of arginine found in an equal weight of protein from white flour. One hundred grams of milk protein will supply more than the optimal daily requirement of all the essential amino acids. a—Enriched bread contained 6% milk solids and high-vitamin yeast.

TABLE 34

Recommended Dietary Allowances, Revised 1945 [1]

(Amounts per Day)

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	Calories	Protein g.	Calcium g.	Iron mg.	Vitamin A I. U.[2]	Thiamine mg.[3]	Riboflavin mg.[3]	Niacin (Nicotinic Acid) mg.[3]	Ascorbic Acid mg.	Vitamin D I. U.
Man (154 lb., 70 kg.)										
Sedentary	2500	70	0.8	12 [4]	5000	1.2	1.6	12	75	[5]
Moderately active	3000	70	0.8	12 [4]	5000	1.5	2.0	15	75	[5]
Very active	4500	70	0.8	12 [4]	5000	2.0	2.6	20	75	[5]
Woman (123 lb., 56 kg.)										
Sedentary	2100	60	0.8	12	5000	1.1	1.5	11	70	[5]
Moderately active	2500	60	0.8	12	5000	1.2	1.6	12	70	[5]
Very active	3000	60	0.8	12	5000	1.5	2.0	15	70	[5]
Pregnancy (latter half)	2500 [6]	85	1.5	15	6000	1.8	2.5	18	100	400 to 800
Lactation	3000	100	2.0	15	8000	2.0	3.0	20	150	400 to 800
Children up to 12 yrs.[7]:										
Under 1 yr.[8]	100/2.2 lb. (1 kg.)	3.5/2.2 lb. (1 kg.)	1.0	6	1500	0.4	0.6	4	30	400 to 800
1–3 yrs. (29 lb., 13 kg.)	1200	40	1.0	7	2000	0.6	0.9	6	35	400
4–6 yrs. (42 lb., 19 kg.)	1600	50	1.0	8	2500	0.8	1.2	8	50	400
7–9 yrs. (55 lb., 25 kg.)	2000	60	1.0	10	3500	1.0	1.5	10	60	400
10–12 yrs. (75 lb., 34 kg.)	2500	70	1.2	12	4500	1.2	1.8	12	75	400

Recommended Dietary Allowances, Revised 1945 [1]

	Calories	Protein g.	Calcium g.	Iron mg.	Vitamin A I. U.[2]	Thiamine mg.[3]	Riboflavin mg.[3]	Niacin (Nicotinic Acid) mg.[3]	Ascorbic Acid mg.	Vitamin D I. U.
Children over 12 yrs.[7]:										
Girls, 13–15 yrs. (108 lb., 49 kg.) .	2600	80	1.3	15	5000	1.3	2.0	13	80	400
16–20 yrs. (119 lb., 54 kg.) .	2400	75	1.0	15	5000	1.2	1.8	12	80	400
Boys, 13–15 yrs. (103 lb., 47 kg.) .	3200	85	1.4	15	5000	1.5	2.0	15	90	400
16–20 yrs. (141 lb., 64 kg.) .	3800	100	1.4	15	6000	1 8	2.5	18	100	400

[1] Tentative goal toward which to aim in planning practical dietaries can be met by a good diet with a variety of natural foods. Such a diet will also provide other minerals and vitamins, the requirements for which are less well known.

[2] The allowance depends on the relative amounts of vitamin A and carotene. The allowances of the table are based on the premise that approximately two-thirds of the vitamin A value of the average diet in this country is contributed by carotene and that carotene has half or less than half the value of vitamin A.

[3] For adults (except pregnant and lactating women) receiving diets supplying 2,000 calories or less, such as reducing diets, the allowances of thiamine, riboflavin, and niacin may be 1 milligram, 1.5 milligrams, and 10 milligrams respectively. The fact that figures are given for different calorie levels for thiamine, riboflavin, and niacin does not imply that we can estimate the requirement of these factors within 500 calories, but they are added merely for simplicity of calculation. Other members of the B complex also are required, though no values can be given. Foods supplying adequate thiamine, riboflavin, and niacin will tend to supply sufficient of the remaining B vitamins.

[4] There is evidence that the male adult needs little or no iron. The allowance will be provided if the diet is satisfactory in other respects.

[5] For persons who have no opportunity for exposure to clear sunshine and for elderly persons, the ingestion of small amounts of vitamin D may be desirable. Other adults probably have little need for vitamin D.

[6] During the latter part of pregnancy the allowance should increase approximately 20% over the preceding level. The value of 2500 calories represents the allowance for pregnant, sedentary women.

[7] Allowances for children are based on the needs for the middle year in each group (as 2, 5, 8, etc.) and are for moderate activity and for average weight at the middle year of the age group.

[8] Needs of infants increase from month to month with size and activity. The amounts given are for approximately 6 to 8 months. The dietary requirements for some of the nutrients such as protein and calcium are less if derived largely from human milk.

Further Recommendations Concerning Table 34

Fat

There is available little information concerning the human requirement for fat. Fat allowances must be based at present more on food habits than on physiological requirements. While a requirement for certain unsaturated fatty acids (the linoleic and arachidonic acids of natural fats) has been amply demonstrated with experimental animals, the human need for these fatty acids is not known. In spite of the paucity of information on this subject there are several factors which make it desirable that fat be included in the diet to the extent of at least 20 to 25% of the total calories and that the fat intake include *essential* unsaturated fatty acids to the extent of at least 1% of the total calories. At higher levels of caloric expenditure, e.g., for a very active person consuming 4500 calories and for children and adolescent persons, it is desirable that 30 to 35% of the total calories be derived from fat. Since foodstuffs such as meat, milk, cheese, and nuts may be expected to contribute *invisible* fat to the extent of from one-half to two-thirds of the total amounts of fat implied by the above proportions of the total calories, it is satisfactory to use separated or *visible* fats such as butter, margarine, lard, and shortenings only to the extent of one-third to one-half of the amounts indicated.

Copper

The requirement for copper for adults is about 1 to 2 milligrams daily. Infants and children require approximately 0.05 milligram for each kilogram of body weight. The requirement for copper is approximately one-tenth that for iron. A good diet normally will supply sufficient copper.

Iodine

The requirement for iodine is small, probably about 0.002 to 0.004 milligram daily for each kilogram of body weight, or a total of 0.15 to 0 30 milligram daily for the adult. This need is met by the regular use of iodized salt; its use is especially important in *adolescence* and *pregnancy*.

Phosphorus

Available evidence indicates that the phosphorus allowances should be at least equal to those for calcium in the diets of children and of women during the latter part of pregnancy and during lactation. In the case of other adults the phosphorus allowances should be approximately 1.5 times those for calcium. In general it is safe to assume that if the calcium and protein needs are met through common foods, the phosphorus requirement also will be covered, because the common foods richest in calcium and protein are also the best sources of phosphorus.

Vitamin K

The requirement for vitamin K usually is satisfied by any good diet. Special consideration needs to be given to newborn infants. Physicians commonly give vitamin K either to the mother before delivery or to the infant immediately after birth.

Salt

The needs for salt and for water are closely interrelated. A liberal allowance of sodium chloride for the adult is 5 grams daily, except for some persons who sweat profusely. The average normal intake of salt is 10 to 15 grams daily, an amount which meets the salt requirements for a water intake up to 4 liters daily. When sweating is excessive, one additional gram of salt should be consumed for each liter of water in excess of 4 liters daily. With heavy work or in hot climates 20 to 30 grams daily may be consumed with meals and in drinking water. Even then, most persons do not need more salt than usually occurs in prepared foods. It has been shown that after acclimatization persons produce sweat that contains only about 0.5 gram to the liter in contrast with a content of 2 to 3 grams for sweat of the unacclimatized person. Consequently after acclimatization, need for increase of salt beyond that of ordinary food disappears.

Water

A suitable allowance of water for adults is 2.5 liters daily in most instances. An ordinary standard for diverse persons is one milliliter for each calorie of food. Most of this quantity is contained in prepared foods. At work or in hot weather, requirements may reach 5 to 13 liters daily. Water should be allowed *ad libitum*, since sensations of thirst usually serve as adequate guides to intake except for infants and sick persons.

TABLE 35

Comparative Values of Dairy Products as Sources of Calcium

Product	Calcium %	Product	Calcium %
Dry Milk Solids-not-Fat	1.20	Skim Milk	0.12
Dry Whole Milk	0.90	Milk	0.11
Cheddar Cheese	0.84	Cream (20% Fat)	0.09
Evaporated Milk	0.27	Cream Cheese	0.07
Cottage Cheese	0.15		

TABLE 36

Approximate Weight of One Gallon of Milk or Cream at Various Temperatures[206]

Temperature F.°	Skim Milk lb.	4% Milk lb.	20% Cream lb.	25% Cream lb.	30% Cream lb.	35% Cream lb.	40% Cream lb.
40	8.660	8.610	8.540	8.500	8.470	8.450	8.420
45	8.665	8.605	8.525	8.485	8.450	8.425	8.395
50	8.650	8.600	8.510	8.470	8.430	8.400	8.370
55	8.645	8.595	8.495	8.450	8.410	8.375	8.345
60	8.640	8.590	8.480	8.435	8.390	8.350	8.320
70	8.630	8.580	8.450	8.400	8.350	8.310	8.270
80	8.620	8.565	8.420	8.370	8.315	8.270	8.230
90	8.600	8.550	8.390	8.340	8.280	8.230	8.190
100	8.580	8.520	8.370	8.310	8.250	8.200	8.150
145	8.470	8.420	8.270	8.220	8.150	8.100	8.045

For all practical purposes, milk testing from 3 to 5% milk fat may be assumed to weigh 8.6 pounds per gallon at 60–70°F.

TABLE 37

Approximate Weight of One Gallon of Various Milk Products at 60°F.

(See also Table 36)

(Water	8.34)
Evaporated Milk (7.9% Fat)	8.89
Condensed Milk (9.5% Fat, no Sugar)	9.05
Condensed Milk (Sweetened)	11.00
Condensed Skim Milk (Unsweetened)	9.18
Condensed Skim Milk (Sweetened)	11.20
Ice Cream Mix* (8% Fat)	9.05
Ice Cream Mix (10% Fat)	9.15
Ice Cream Mix (12% Fat)	9.07
Ice Cream Mix (14% Fat)	8.97
Skim Milk	8.64
Milk Fat (Butter Oil)	7.5

* The finished ice cream with 100% overrun will weigh one-half that of the ice cream mix.

Table 38

Dairy Products Manufactured in the United States, 1939–1945 [205]

Product	1945 [a] 1,000 pounds	1944 1,000 pounds	1943 1,000 pounds	1942 1,000 pounds	1941 1,000 pounds	1940 1,000 pounds	1939 1,000 pounds
Creamery Butter (Including Whey Butter)	1,361,790	1,488,502	1,673,788	1,764,054	1,872,183	1,836,826	1,781,737
American Cheese:							
Whole Milk	872,831	804,787	765,089	916,850	753,122	602,790	537,298
Part Skim	1,112	2,248	4,670	3,759	4,139	3,890	4,247
Full Skim	2,172	2,628	2,337	1,001	416	247	236
Swiss Cheese (Including Block)	50,065	45,571	45,626	52,561	55,962	48,659	42,631
Brick and Munster Cheese	14,793	27,435	27,978	28,798	32,066	34,328	34,969
All Italian Varieties of Cheese	66,824	41,721	43,003	34,916	34,363	25,002	20,509
Cream Cheese and Neufchatel	69,636	60,410	70,451	47,554	50,012	51,183	47,961
All Other Varieties of Cheese	44,470	35,004	36,477	27,876	26,497	19,638	20,912
Cottage Cheese	[d]	224,374	213,910	196,799	187,595	174,257	166,720
Sweetened Condensed Milk:							
Case Goods, Unskimmed	142,958	139,115	117,247	62,453	114,772	61,955	34,732
Bulk Goods, Skimmed	512,943	370,049	306,899	225,840	173,658	166,017	152,886
Bulk Goods, Unskimmed	76,762	63,586	66,588	75,382	79,299	76,138	54,897
Unsweetened Condensed Milk:							
Bulk Goods, Skimmed	451,133	367,831	325,512	318,379	326,535	246,910	223,001
Bulk Goods, Unskimmed	127,074	119,405	102,452	125,880	113,965	128,017	107,026
Evaporated Milk (Unsweetened):							
Case Goods, Unskimmed	3,776,477	3,428,089	3,057,274	3,518,504	3,246,547	2,464,668	2,170,601
Concentrated Skim Milk (for Animal Feed)	13,278	20,489	......	......	......	......	......
Condensed or Evaporated Buttermilk	158,981	157,503	167,338	169,999	128,183	111,842	104,288
Dry or Powdered Buttermilk	48,493	56,683	60,995	69,637	75,614	67,931	62,187
Dry or Powdered Whole Milk	217,883	177,754	137,766	62,167	45,627	29,409	24,472

TABLE 38 (*Cont.*)

Dairy Products Manufactured in the United States, 1939-1945 [206]

Product	1945 [a] 1,000 pounds	1944 1,000 pounds	1943 1,000 pounds	1942 1,000 pounds	1941 1,000 pounds	1940 1,000 pounds	1939 1,000 pounds
Total Nonfat Dry Milk Solids for Human Consumption .	643,745	582,869	509,620	565,414	366,455	321,843	267,860
Spray Process	298,741	266,400	245,596	(No segregation in records prior to 1943)			
Roller Process	345,004	316,469	264,024	(No segregation in records prior to 1943)			
Nonfat Dry Milk Solids for Animal Feed	17,602	16,397	24,279	61,148	110,042	159,962	140,520
Dry or Powdered Whey	134,772	141,553	110,158	124,479	111,316	90,996	56,341
Dried Casein (Skim Milk or Buttermilk Product)	11,906	14,883	18,386	42,268	47,346	46,616	40,878
	1,000 gallons	1,000 gallons	1,000 gallons	1,000 gallons	1,000 gallons	1,000 gallons	1,000 gallons
Ice Cream	475,009	444,277	412,089	464,146	390,175	318,088	304,522
Sherbets (does not include water ice)	70,299	49,481	47,218	8,772	8,060	8,089	[c]13,793
Ice Milk	[d]	9,038	10,041	14,002	13,980	11,878	[b]

[a] Preliminary.

[b] No manufacture reported.

[c] Includes ice milk.

[d] Not available.

TABLE 39

(See also Table 38)

Production and Per Capita Consumption of Dairy Products[1]

Product	1945	1939	1930	1925
Milk				
Production (1)	121,744	106,651	99,998	92,156
Consumption (2)	867	810	808	796
Milk and Cream (used as such)				
Production (1)	58,428	45,223	43,273	40,422
Consumption (2)	438	344	351	354
Butter				
Production (1)	1,699	2,210	2,121	2,074
Consumption (2)	12.1	16.8	17.1	17.9
Cheese (3)				
Production (1)	1,115	709	500	491
Consumption (2)	7.9	5.4	4.0	4.2
Evaporated Milk				
Production (1)	3,776	2,171	1,449	1,202
Consumption (2)	26.9	16.5	11.7	10.4
Ice Cream				
Production (1)	2,233	1,431	1,132	1,085
Consumption (2)	15.9	10.9	9.1	9.4
Dried Whole Milk				
Production (1)	219	24	15	9
Consumption (2)	1.56	0.18	0.12	0.08
Non-Fat Milk Solids				
Production (1)	644	268	...	...
Consumption (2)	4.6	2.0	...	...

(1) million pounds; (2) pounds per capita; (3) full skim, pot and baker's cheese omitted.

TABLE 40

Percentage of Fats and Oils Used in the Manufacture of Oleomargine[204]

	1940 %	1941 %	1942 %	1943 %	1944 %
Animal Fats	9.4	10.8	10.9	7.0	5.6
Domestic Vegetable Oils	79.7	76.9	87.4	93.0	94.4
Cottonseed	45.0	50.5	48.0	50.4	44.9
Soybean	33.8	25.5	38.5	39.6	44.1
Foreign Vegetable Oils	10.9	12.3	1.7	...	...
Coconut	8.5	10.0	1.0	...	...
Other Oils	2.4	2.3	0.7	...	...
Milk (1000 pounds)	60,961	67,323	74,875	104,389	101,642

TABLE 41

Production and Per Capita Consumption of Margarine [204]

Year	Production of Uncolored Margarine (1000 pounds)	Production of Colored Margarine (1000 pounds)	Per Capita Consumption (pounds)
1939	299,412	1,445	2.3
1940	317,952	2,451	2.4
1941	362,813	4,774	2.7
1942	361,262	64,488	2.7
1943	497,601	116,543	3.7
1944	480,617	107,568	3.6

BIBLIOGRAPHY

1. United States Department of Agriculture, Bur. Agri. Economics: *The Dairy Situation*, Sept. (1946).
2. H. C. Sherman: *Chemistry of Food and Nutrition*, New York, The Macmillan Co., (1937).
3. H. Erlenmeyer and H. Gaertner: Heavy Water Content of Water from Milk, *Helv. Chim. Acta.*, 17, 549 (1934).
4. G. O. Burr, M. N. Burr and E. S. Miller: Fatty Acids Essential in Nutrition, *J. Biol. Chem.*, **97**, 1 (1932).
5. W. D. Salmon and J. G. Goodman: Alleviation of Vitamin B Deficiency in the Rat by Certain Natural Fats and Synthetic Esters, *J. Nutrition*, **13**, 477–500 (1937).
6. W. F. Drea: Spectrum Analysis of Milk Ashes, *J. Nutrition*, **8**, 229 (1934).
7. J. C. Marquardt: Calculating the Composition of Milk From the Fat Test Alone, *Food Ind.*, June (1934).
8. A. Bartlett: Variation in Solids-Not-Fat Content of Milk, *J. Dairy Research*, **5**, 113 (1934).
9. A. G. Woodman: *Food Analysis*, New York, McGraw-Hill Co., 1931.
10. L. S. Palmer and H. J. Weise: Substances Adsorbed on the Fat Globules in Cream and Their Relation to Churning, *J. Dairy Sci.*, **17**, 29 (1934).
11. R. Hoagland and G. G. Snider: Nutritive Properties of Animal and Vegetable Fats, U. S. Dept. Agri., *Technical Bull. 725* (1940).
12. G. E. Holm. P. A. Wright and E. F. Deysher: The Phospholipids in Milk, *J. Dairy Sci.*, **16**, 445 (1933).
13. L. M. Lampert: Cholesterol as a Measure of Egg Yolk in Ice Cream, *Ind. Eng. Chem., An. Ed.*, **2**, 159 (1930).
14. S. Ansbacher and G. C. Supplee: Cholesterol Content and Antirachitic Activities of Milk, *J. Biol. Chem.*, **105**, 391 (1934).
15. Association of Official Agricultural Chemists: *Methods of Analysis*, 6th Ed., Washington, D. C., 1945.
16. T. S. G. Jones: Determination of Lactose and Glucose in Milk, *J. Dairy Research*, **7**, 41 (1936).

17. M. Polonovski and A. Lespagnol: Nouvelles acquisitions sur les composés glucosidiques du lait de femme, *Bul. Soc. Chim. Biol.*, **15**, 320 (1933).
18. E. O. Whittier: Lactose and Its Utilization: A Review, *J. Dairy Sci.*, **27**, 505 (1944).
19. R. A. Gortner: *Outlines of Biochemistry*, New York, J. Wiley and Sons, 1938.
20. E. O. Whittier and Lore Rogers: Continuous Fermentation in the Production of Lactic Acid, *Ind. Eng. Chem.*, **23**, 532 (1931).
21. G. T. Peckham, Jr.: The Commercial Manufacture of Lactic Acid, *Chem. Eng. News*, **22**, 440 (1944).
22. E. M. Filachione and C. H. Fisher: Lactic Acid Condensation Polymers, *Ind. Eng. Chem.*, **36**, 223 (1944).
23. Associates of Rogers: *Fundamentals of Dairy Science*, New York, Reinhold Pub. Co., 1935.
24. E. O. Whittier, C. A. Carey and N. R. Ellis: Effects of Lactose on Growth and Longevity, *J. Nutrition*, **9**, 521 (1935).
25. E. J. Schantz, C. A. Elvehjem and E. B. Hart: The Relation of Fat to the Utilization of Lactose in Milk, *J. Biol. Chem.*, **122**, 381 (1938).
26. E. O. Whittier: Methods for Manufacturing Acid-Precipitated Casein from Skim Milk, *U. S. Dept. Agri. Circ. 279* (1942).
27. E. Sutermeister and F. L. Browne: *Casein and Its Industrial Applications*, New York, The Chemical Catalog Co., Inc., 1939.
28. American Plastics Corporation, New York. *Personal Correspondence* (1946).
29. E. O. Whittier and S. P. Gould: Making Casein Fiber, *Ind. Eng. Chem.*, **32**, 906 (1940).
30. A. E. Brown, W. G. Gordon, E. C. Gall and R. W. Jackson: Acetylated Casein Fiber, *Ind. Eng. Chem.*, **36**, 1171 (1944).
31. T. L. McMeekin, T. S. Reid, R. C. Warner and R. W. Jackson: Artificial Bristles from Proteins, *Ind. Eng. Chem.*, **37**, 685 (1945)
32. L. S. Palmer: The Structure and Properties of the Natural Fat Globule "Membrane," *J. Dairy Sci.*, **27**, 471 (1944).
33. F. Kieferle and J. Gloetzle: Residual Nitrogen of Cow's Milk, *Milchwirtschaft. Forsch.*, **11**, 62 (1930).
34. League of Nations' Health Organization, *Bull. 7*, 460 (1938).
35. L. S. P. Davidson, H. W. Fullerton, J. W. Howie, J. M. Croll, J. M. Orr and W. Godden: Observations on Nutrition in Relation to Anemia, *Brit. Med. J.* **1**, 685 (1933).
36. H. C. Sherman and E. Hawley: Calcium and Phosphorus Metabolism in Childhood, *J. Biol. Chem.*, **53**, 375 (1922).

37. Amy L. Daniels, M. K. Hutton, E. Knott, G. Everson and O. Wright: Relation of Ingestion of Milk to Calcium Metabolism in Children, *Am. J. Diseases Children,* **47**, 499 (1934).
38. R. B. French and G. R. Cowgill: Immaturity of the Organism as a Factor Determining the Favorable Influence of Lactose on the Utilization of Calcium and Phosphorus, *J. Nutrition,* **44,** 383 (1937).
39. G. A. Koestler: The Detection of Milk Altered by Secretion Disturbances, *Mitt. Geb. Lebensmittel Untersuchungen Hyg.,* **11,** 154 (1920).
40. C. A. Elvehjem, E. B. Hart and W. C. Sherman: Availabilty of Iron from Different Sources for Hemoglobin Formation, *J. Biol. Chem.* **103,** 61 (1933).
41. R. Stugart: Determination of Iron in Milk and Other Biological Materials, *Ind. Eng. Chem. An. Ed.,* **3,** 390 (1931).
42. C. A. Elvehjem, D. Duckles and D. R. Mendenhall: Iron versus Iron and Copper in the Treatment of Anemia in Infants, *Am. J. Diseases Children,* **53:** 785 (1937).
43. I. Leitch and J. M. Henderson: Estimation of Iodine in Foodstuffs and Body Fluids, *Biochem. J.,* **20,** 1003 (1926).
44. J. F. McClendon, R. E. Remington, H. von Kolnitz and R. Redding: Determination of Traces of Iodine in Milk, Butter, Oil and Urine, *J. Am. Chem. Soc.,* **52:** 541 (1930).
45. J. G. Archibald: Zinc in Cow's Milk, *J. Dairy Sci.,* **27,** 257 (1944).
46. N. Lunin, *Z. Physiol. Chem.* **5,** 31 (1881).
47. F. G. Hopkins: The Analyst and the Medical Man, *Analyst,* **31,** 385 (1906).
48. E. V. McCollum and M. Davis: Necessity of Certain Lipins in the Diet During Growth, *J. Biol. Chem.* **15,** 167 (1913).
49. T. B. Osborne and L. B. Mendel: The Influence of Butter Fat on Growth, *J. Biol. Chem.,* **16,** 423 (1913).
50. C. J. Funk, *State Med.,* **20,** 341 (1912).
51. W. H. Eddy and G. Dalldorf: *The Avitaminoses,* Baltimore, Williams and Wilkins Co., 1944.
52. T. S. Sutton and W. E. Krause: Vitamin A in Milk, *Ohio Agri. Expt. Sta. Bi-Monthly Bull. 164* (1933).
53. K. M. Henry, J. Houston, S. K. Kon and L. W. Osborne: The Effect of Commercial Drying and Evaporation on the Nutritive Properties of Milk, *J. Dairy Research,* **10,** 272 (1939).
54. U. S. Dept. Agri., *Misc. Pub. 571:* Vitamin A in Butter, (1945).
55. C. Eykman, *Virchow's Arch. Path. Anat.* **148,** 523; **149,** 187 (1897) also C. Eykman and G. Grijns, *Arch. Hyg.,* **58,** 150 (1906).

56. R. R. Williams and T. D. Spies: *Vitamin B_1 (Thiamin) and Its Use in Medicine,* New York, The Macmillan Co., 1939.
57. G. R. Cowgill: *The Vitamin B Requirement of Man,* New Haven, Yale Univ. Press, 1934.
58. N. J. Kendall: Thiamine Content of Various Milks, *J. Pediat.,* **20,** 65 (1942).
59. J. Houston, S. K. Kon and S. Y. Thompson: The Effect of Commercial Pasteurization and Sterilization on the Vitamin B_1 and Riboflavin Content of Milk as Measured by Chemical Methods, *J. Dairy Research,* **11,** 67 (1940).
60. A. D. Holmes, H. G. Lindquist, C. P. Jones and A. W. Wertz: Effect of High Temperature, Short Time Pasteurization on the Ascorbic Acid, Riboflavin and Thiamin Content of Milk, *J. Dairy Sci.,* **28,** 29 (1945).
61. O. E. Stamberg and D. R. Theophilus: A Photolysis of Riboflavin in Milk, *J. Dairy Science,* **28,** 269 (1945).
62. M. R. Shetlar, C. L. Shetlar and J. F. Lyman: Determination of Riboflavin in Chocolate Milk and the Comparative Photochemical Losses in Chocolate and Whole Milk, *J. Dairy Sci.,* **28,** 873 (1945).
63. A. Z. Hodson: The Nicotinic Acid, Pantothenic Acid, Choline and Biotin Content of Fresh, Irradiated, Evaporated and Dry Milk, *J. Nutrition,* **29,** 137 (1945).
64. I. Kerlan and R. P. Herwick: Calcium Pantothenate for Human Achromotrichia, *J. Am. Med. Assoc.,* **123,** 391 (1943).
65. D. F. Reid, S. Lepkovsky, D. Bonner and E. L. Tatum: The Intermediary Metabolism of Trytophane in Pyridoxine-Deficient Rats, *J. Biol. Chem.,* **155,** 299 (1944).
66. L. D. Wright, H. R. Skeggs, A. D. Welch, K. L. Sprague and P. A. Mattis: The Existence of a Microbiologically Inactive "Folic Acid"—like Material Possessing Vitamin Activity in the Rat, *J. Nutrition,* **92,** 289 (1945).
67. M. N. Coryell, M. E. Harris, S. Miller and Icy G. Macy: Human Milk Studies, XXII. Nicotinic Acid, Pantothenic Acid, and Biotin Contents of Colostrum and Mature Human Milk, *Am. J. Diseases Children,* **70,** 150 (1945).
68. R. W. Engle: The Choline Content of Animal and Plant Products, *J. Nutrition,* **25:** 441 (1943).
69. R. J. Williams, V. H. Cheldelen and H. K. Mitchell: The Vitamin B Content of Milk from Different Species. Studies on the Vitamin Content of Tissues, 11. *Publication 4237, Univ. Texas,* 97 (1942).
70. C. G. King: The Chemistry of Vitamin C, *J. Am. Med. Assoc.,* **111,** 1462 (1938).

71. F. F. Tisdall: Vitamins in Infancy and Childhood, *Nutrition in Everyday Practice*, Canadian Med. Assoc. (1939).
72. S. K. Kon and M. B. Watson: The Vitamin C Content of Cow's Milk, *J. Biochem.*, 31, 223 (1937).
73. C. H. Whitnah and W. H. Riddell: Variations in the Vitamin C Content of Milk, *J. Dairy Sci.*, 20, 9 (1937).
74. D. B. Hand: Reduced and Total Vitamin C in Milk, *J. Dairy Sci.*, 26, 7 (1943).
75. W. W. Woessner, C. A. Elvehjem and H. A. Schuette: The Determination of Ascorbic Acid in Evaporated, Powdered Milk and Powdered Milk Products, *J. Nutrition*, 20, 327 (1940).
76. T. M. Olson and G. C. Walker: Vitamin D in Milk, *So. Dak. Agri. Expt. Sta. Bull. 296* (1935).
77. W. C. Russel, D. E. Wilcox, J. Waddell and L. T. Wilson: The Relative Value of Irradiated Yeast and Irradiated Ergosterol in the Production of Vitamin D Milk, *J. Dairy Science*, 17, 445 (1934).
78. K. S. Weckel and H. C. Jackson: The Irradiation of Milk, *Wis. Agri. Expt. Sta. Research Bull. 136* (1939).
79. Council on Foods and Nutrition: Fortification of Milk with Vitamins and Minerals, *J. Am. Med. Assoc.*, 126, 432 (1944).
80. G. R. Cowgill: Nutrition—A Factor Important for Industrial Hygiene, *J. Am. Pub. Health Assoc.*, 34, 630 (1945).
81. R. S. Breed: Thermophilic Bacteria in Milk Pasteurized by the Holding Process, *N. Y. Agri. Expt. Sta. (Geneva), Tech. Bull. 191* (1932).
82. J. M. Frayer: The Influence of Delayed Cooling Upon the Quality of Milk, *Ver. Agri. Expt. Sta. Bull. 313* (1930).
83. *Standard Methods for the Examination of Dairy Products, 8th. Ed.* Am. Pub. Health Assoc. New York, (1941).
84. C. F. Hoyt: Counting Bacteria in Ice Cream, *Monthly Bull. Calif. Dept. Agri.*, 21, 409 (1932).
85. Ministry of Health, London, Eng. *Statutory Rules and Orders (The Milk Regulations), No. 10*, Jan. 2, 1946.
86. C. S. Bryan, W. I. Mallman and G. J. Turney: Some Microscopic Technics for Determining the Bacteriological Quality of Milk, *Mich. Agri. Expt. Sta. Cir. Bull. 186* (1943).
87. C. K. Johns and R. K. Howson: Potentiometric Studies with Resazurin and Methylene Blue in Milk, *J. Dairy Sci.*, 23, 295 (1940).
88. C. K. Johns: Concerning the Accuracy of the Methylene Blue Reduction Test, *J. Dairy Sci.*, 21, 227 (1938).
89. *Standard Methods of Water Analysis, 8th Ed.*, Am. Pub. Health Assoc., New York (1936).

90. J. D. Wildman: Development of Methods for the Estimation of Mold in Cream or Butter, *J. Assoc. Official Agr. Chem.*, **20**, 93–100 (1937).
91. W. V. Halvorson, V. A. Cherrington and H. C. Hansen: Labortory Methods For The Detection of Milk From Cows Infected With Mastitis, *J. Dairy Sci.*, **17**, 281 (1934).
92. G. J. Hucker: The Detection and Control of Bovine Mastitis, *J. Dairy Sci.*, **18**, 469 (1935).
93 J. W. Frayer: Mastitis-Laboratory Tests and Their Interpretation, *J. Milk Technology*, **7**, 89 (1944).
94. L. W. Slanetz and J. Naghski: Studies on Streptococci of Bovine Mastitis, *J. Infectious Diseases*, **66**, 80 (1940).
95. J. M. Murphy and J. J. Hanson: The Whiteside Test for the Detection of Chronic Bovine Mastitis, *Cornell Vet.*, **31**, 47 (1941).
96. H. O. Dunn, J. M. Murphy and O. F. Garrett: Nature of the Material Responsible for the Modified Whiteside Test for Mastitis, *J. Dairy Sci.*, **26**, 295 (1943).
97. *U. S. Dept. Agri. Circular 672,* The Hotis Test for the Detection of Mastitis Bacteria (1942).
98. F. S. Jones and R. B. Little: The Bactericidal Property of Cow's Milk, *J. Exp. Med.* **45**, 319 (1927).
99. F. S. Jones and H. S. Simms: Bacterial Growth Inhibitor (Lactenin) In Milk, *J. Exp. Med.* **51**, 327 (1930).
100. C. S. Morris: The Presence in Raw Milk of a Bactericidal Substance Specific for Certain Strains of Coliform Organisms and the Comparative Rate of Growth of Bacteria in Raw and Pasteurized Milk, *Dairy Ind.*, **10**, 180 (1945).
101. L. M. Lampert: Chlorine as a Sterilizing Agent for Dairy Use, *Monthly Bull. Calif. Dept. Agri.* **33**, 168 (1944).
102. J. M. Frayer: Non-Chlorine Materials for the Germicidal Treatment of Dairy Untensils, *Ver. Agri. Expt. Sta. Bull. 511* (1944).
103. M. E. Parker: Acid Detergents in Food Sanitation, *Ind. Eng. Chem.* **38**, 100 (1943).
104. A. S. DuBois and D. D. Dibblee: The Influence of Surface Active Cationic Germicides on the Bactericidal Population of Milk. *J. Milk Technology*, **9**: 260 (1946).
105. W. L. Mallman, E. W. Kivela and C. Turner: Sanitizing Dishes, *Soap Sanit. Chemicals,* **130**, 133 (1946).
106. G. C. Supplee, G. E. Flanagan and O. G. Jensen: The Lethal Effectiveness of Ultra-Violet Rays Applied to Milk, *J. Dairy Sci.*, **24**, 1055 (1941).
107. C. L. Roadhouse and G. A. Koestler: Contribution to the Knowledge of the Taste of Milk, *J. Dairy Sci.*, **12**, 421 (1929).

108. C. L. Roadhouse and J. L. Henderson: Flavors of Milk and Their Control. *Calif. Agri. Expt. Sta. Bull. 595* (1935).
109. V. N. Krukovsky and E. S. Guthrie: Ascorbic Acid as a Key Factor in the Inhibition or Promotion of a Tallowy Flavor in Milk. *J. Dairy Sci.*, **28**, 565 (1945).
110. N. P. Tarassuk: Rancid Flavor in Milk. *Internatl. Assoc. Milk Dealers, Bull.* 32, 153 (1939).
111. C. S. Bryan and G. M. Trout: The Influence of Streptococci of the Udder on the Flavor, Chloride Content and the Bacteriological Quality of the Milk Produced. *J. Dairy Sci.*, **18**, 777 (1935).
112. G. M. Trout and D. V. McMillan: Absorption of Odors by Milk. *Mich. Agri. Expt. Sta. Tech. Bull. 181* (1943).
113. B. W. Hammer and R. V. Hussong: Observations of the Heat Resistance of Some Ropy Milk Organisms. *J. Dairy Sci.*, **14**, 27 (1931).
114. N. N. Allen, H. A. Lardy and H. F. Wilson: The Effect of Ingestion of DDT Upon Dairy Cows. *J. Dairy Sci.*, **29**, 530 (1946).
115. W. T. Sedgwick: *Principals of Sanitary Science and Public Health*, New York (1901).
116. G. H. Wilster: Vacuum Pasteurization of Cream for Butter. *Ore. Agri. Expt. Sta. Bull. 368* (1940).
117. L. M. Thurston and H. C. Olson: The Bacterial Flora of High Grade Milk Before and After Pasteurization. *W. Va. Agri. Expt. Sta. Bull. 255* (1933).
118. L. I. Katzin, L. A. Sandholzer and M. E. Strong: Application of the Decimal Reduction Time Principle to a Study of the Resistance of Coliform Bacteria to Pasteurization. *J. Bact.*, **45**, 265 (1943).
119. A. C. Dahlberg: The Relationship of the Growth of All Bacteria and Coliform Bacteria in Pasteurized Milk Held at Refrigeration Temperatures. *J. Dairy Sci.*, **29**, 651 (1946).
120. J. L. Hileman, H. Leber and M. L. Speck: Thermoduric Bacteria in Pasteurized Milk. *J. Dairy Sci.*, **24**, 305 (1941).
121. G. Leighton and P. J. McKinley: *Milk Consumption and Growth of School Children*, H. M. Stationery Office, London (1930).
122. Fischer and Bartlett. *Nature*, **127**, 591 (1931).
123. L. C. Frank and Others: Do Children Who Drink Raw Milk Thrive Better Than Children Who Drink Heated Milk, *U. S. Public Health Reports*, **47**, 1951 (1932).

124. C. A. Elvehjem, E. B. Hart, H. C. Jackson and K. G. Weckel: The Nutritional Value of Milks, Raw vs. Pasteurized and Summer vs. Winter, *J. Dairy Sci.*, **17**, 763 (1934).
125. A. C. Knapp, E. S. Godfrey, and W. L. Aycock: *Outbreaks of Poliomyelitis, Apparently Milk Borne. J. Am. Med. Assoc.*, **87**, 235 (1926).
126. W. L. Aycock: Milk Borne Epidemic of Poliomyelitis, *Am. J. Hyg.* **7**, 791 (1927).
127. A. Rosenow: Institutional Outbreak of Poliomyelitis Apparently Due to Streptococcus in Milk, *J. Inf. Dis.*, **50**, 377 (1932).
128. Roland H. Berg: *The Challenge of Polio*, New York, The Dial Press, 1946.
129. R. L. Cecil: *Textbook of Medicine*, Philadelphia, W. B. Saunders, 1945.
130. J. F. Huddelson: *Brucellosis in Man and Animals*, New York, The Commonwealth Fund, 1943.
131. Anon.: Milk Sickness; A Retrospect, *J. Am. Med. Assoc.*, **128**, 734 (1945).
132. F. Crouch: Trembles (or Milk Sickness), *U. S. Dept. Agri. Circ. 306* (1933).
133. O. C. Cunningham and L. H. Addington: Tuberculosis in Goats, *J. Dairy Sci.*, **19**, 435 (1936).
134. Report of Special Board of U. S. Public Health Service: The Montreal Typhoid Fever Situation, *Am. J. Pub. Health*, **17**, 783 (1927).
135. Anon.: California Acts on Cheese-borne Typhoid Fever, *Am. J. Pub. Health*, **34**, 840 (1944).
136. W. A. Halvorson: Preliminary Report of Typhoid Fever Due to Unpasteurized Cheese, *California's Health*, **1**, 171–173 (1944).
137. G. M. Dack: *Food Poisoning*, Chicago, Univ. Chicago Press, (1943).
138. Public Health Service Milk Ordinance and Code, U. S. Treasury Dept., *Public Health Bull. 220* (1936).
139. B. W. Hammer and F. J. Babel: Bacteriology of Butter Cultures—A. Review, *J. Dairy Sci.*, **26**, 83 (1943).
140. C. L. Roadhouse and E. E. Brown: A Method of Preparing Churned Cultured Buttermilk, *Calif. Agri. Expt. Sta. Cir. 339* (1936).
141. F. L. Wilson and F. W. Turner: Acid-Milk Hazard, *Food Research*, **10**, 122 (1945).
142. F. J. Doan and D. C. Dahle: The Manufacturing Process for Commercial Sour Cream, *Pa. Agri. Expt. Sta. Bull. 233* (1928).

143. L. F. Rettger, M. N. Levy, L. Weinstein and J. E. Weiss: *Lactobacillus Acidolphilus and Its Therapeutic Application*, New Haven, Yale Univ. Press, 1935.
144. T. Rosebury: The Problem of Dental Caries, *Arch. Path.*, **15**, 260 (1933).
145. E. G. Whittle: Goat's Milk and Human Milk, *Analyst*, **68**, 247 (1943).
146. F. J. Doan and J. L. Dizikes: Digestion Characteristics of Various Types of Milk Compared with Human Milk, *Penn. Agri. Expt. Sta. Bull. 428* (1942).
147. G. Steinert and G. Papp: Frauenmilch und Menstruation, *Zeitschr. Kinderheilk*, **56**, 208–211 (1934).
148. E. V. McCollum, E. Orent-Keiles and H. G. Day: *The Newer Knowledge of Nutrition*, New York, The Macmillan Co., (1939).
149. H. H. Perlman, A. M. Dannenberg and N. Sokoloff: The Excretion of Nicotine in Breast Milk and Urine from Cigaret Smoking, *J. Am. Med. Assoc.*, **120**, 1003 (1942).
150. J. A. Gamble, N. R. Ellis and A. K. Bede: Composition and Properties of Goat's Milk as Compared with Cow's Milk, *U. S. Dept. Agri. Tech. Bull. 671* (1939).
151. A. D. Holmes, H. G. Lindquist and E. K. Greenwood: Variation in Fat, Ascorbic Acid and Riboflavin Content of Goat's Milk, *J. Dairy Sci.*, **28**, 853 (1945).
152. L. H. Burgwald: Increasing the Viscosity of Cream, *Milk Dealer*, **29**, (6)52–54 (1940).
153. P. H. Tracy and W. J. Corbett: Coffee as a Factor in the Feathering of Cream, *J. Dairy Sci.*, **21**, 483 (1938).
154. C. H. Getz, G. F. Smith and P. H. Tracy: Instant Whipping of Cream by Aeration, *J. Dairy Sci.*, **19**, 490 (1936).
155. C. R. Havig-Horst: Cream DeLuxe, *Food Industries*, Aug. (1945).
156. F. J. Doan and R. W. Mykleby: Critical Study of the U. S. Public Health Service Definition for Homogenized Milk with Some Recommendations, *J. Dairy Sci.*, **26**, 893 (1943).
157. G. M. Trout: Homogenized Milk and Public Health, *J. Milk Technology*, **6**, 214 (1943).
158. F. J. Doan: Soft Curd Milk. A Critical Review of the Literature, *J. Dairy Sci.*, **21**, 739 (1938).
159. E. P. Brown: Homogenization of Milk by Sonic Vibration, *Milk Plant Monthly*, **30**, No. 3, 52 (1941).
160. V. Conquest, A. W. Turner and H. J. Reynolds: Soft Curd Milk Produced with Pancreatic Concentrate, *J. Dairy Sci.*, **21**, 361–368 (1938).

161. J. F. Lyman, E. H. Browne and H. E. Otting: Readjustment of Salts in Milk by Base-Exchange Treatment, *Ind. Eng. Chem.*, **25**, 1297 (1933).
162. J. H. Hess, H. G. Poncher and H. Woodward: Factors Influencing the Utilization of Calcium and Phosphorus of Cow's Milk, *J. Diseases Children*, **48**, 1058 (1934).
163. M. Morris and G. A. Richardson: Production and Use of Soft Curd Milk, *J. Pediatrics*, **3**, 449 (1933).
164. W. S. Mueller and M. R. Cooney: The Effect of Cocoa Upon the Utilization of the Calcium and Phosphorus of Milk, *J. Dairy Sci.*, **26**, 951 (1943).
165. M. Eichelberger: The Importance of Economical Milk in Human Nutrition, *Am. J. Pub. Health*, **30**, 169 (1940).
166. F. J. Doan and D. V. Josephson: Additional Observation on the Stability of Ascorbic Acid and Sodium l-Ascorbate in Evaporated Milk, *J. Dairy Sci.*, **29**, 625 (1946).
167. S. Freeman and A. C. Ivy: A Comparison of Rats Fed an Evaporated Milk With Those Fed a Milk in Which the Naturally Occurring Fat Has Been Replaced with Coconut Oil, *J. Dairy Sci.*, **25**, 877 (1942).
168. S. T. Coulter and R. Jenness: Packing Dry Whole Milk in Inert Gas, *Minn. Agri. Expt. Sta. Research Bull. 167* (1945).
169. C. M. O'Malley and E. J. Baldi: Composition and Thiamin and Riboflavin Content of Defatted Milk Solids, *J. Milk Technology*, **5**, 138 (1942).
170. P. F. Sharp, J. B. Shield and A. P. Stewart, Jr.: Spray Dried Whole Milk, *Proc. Inst. Food Tech.*, **54**, 7 (1945).
171. American Dry Milk Institute, Inc., *The Grading of Dry Milk Solids*, Chicago, 1942.
172. British Intelligence Objectives Committee, Final Report No. 86, Items 22 and 31, *Some Developments in Dairying in Germany*, London, H. M. Stationery Office, 1946.
173. Cherry-Burrell Corp.: *The Butter Plant of Tomorrow*, Chicago, 1946.
174. Anon.: CP Continuous Buttermaking Process, *J. Milk Technology*, **9**, 351–355 (1946). See also, U. S. Patent 2,406,819 (1946).
175. Official U. S. Standards for Grades of Creamery Butter, *Federal Register*, **8**, 122 (1943).
176. M. Grimes: A Study of Certain Bacteria, Yeasts and Molds on the Keeping Quality of Butter in Cold Storage, *J. Dairy Sci.*, **6**, 427 (1923).
177. H. Wolochow and E. G. Hood: Studies on Surface Taint Butter, *Sci. Agri.* **22**, No. 8, 9, 10 (1942).

178. U. S. Dept. Agri.: *Vitamin A in Butter,* Misc. Pub. 571 (1945).
179. Anon.: The Comparative Nutritional Value of Butter and Oleomargarine, *J. Am. Med. Assoc.,* **119,** 17 (1942).
180. H. J. Deuel, Jr.: The Butter-Margarine Controversy, *Science,* **103,** 183 (1946).
181. U. S. Dept. Agri., *Varieties of Cheese, Descriptions and Analyses, Bull. 608* (1932).
182. W. V. Price: Cheddar Cheese from Pasteurized Milk, *Wis. Agri. Expt. Sta. Bull. 464* (1944).
183. A. C. Dahlberg and J. C. Marquardt: Ripening Cheese in Cans, *N. Y. Agri. Expt. Sta. (Geneva) Tech. Bull. 265* (1942).
184. H. H. Sommer and H. L. Templeton: The Making of Processed Cheese, *Wis. Agri. Expt. Sta. Research Bull. 137* (1939).
185. N. E. Fabricus and V. H. Nielsen: Blue Cheese, U. S. Patent 2,360,556 (1944).
186. D. V. Josephson and C. D. Dahle: A New Cellulose Gum Stabilizer for Ice Cream, *Ice Cream Review,* **28,** (11) 32, 76, 78, 80 (1945).
187. A. T. R. Mattich, E. R. Hiscox, E. L. Crossley, C. H. Lea, J. D. Finlay, J. A. B. Smith, S. Y. Thompson, S. K. Kon and J. W. Egdell: The Effect of Temperature of Preheating, of Clarifying and Bacterial Quality of the Raw Milk on the Keeping Properties of Whole Milk Powder Dried by the Kestner Spray Process, *J. Dairy Research,* **14,** 116 (1945).
188. C. L. Hills: Some Theoretical Aspects of the "New Way" Butter Process, *Australian J. Dairy Technology,* **1,** No. 2 (1946).
189. P. H. Tracy and S. L. Tuckey: Accuracy of Methods of Sampling Milk Deliveries at Milk Plants, *Ill. Agri. Expt. Stat. Bull.,* **459,** (1939).
190. L. M. Lampert and J. H. Brandon: The Babcock Fat Test on Homogenized Milk, *J. Milk Technology,* **8,** No. 3 (1945).
191. T. Mojonnier and H. C. Troy: *Technical Control of Dairy Products,* Chicago, Mojonnier Bros. Co., 1925.
192. L. M. Lampert: Uses of the Lactometer, *Milk Dealer,* **28,** No. 3, 25, 50 (1938).
193. L. M. Lampert: Nomograph for Correction of Lactometer Readings and Calculation of Milk Solids, *Ind. Eng. Chem.,* **12,** 527–528 (1940).
194. L. H. Burgwald: The Phosphatase Test. A Review of the Literature on Its Application for Detecting Irregularities in the Pasteurization of Milk and Dairy Products, *J. Dairy Sci.,* **22,** 853–873 (1939).

195. R. K. Froker and C. M. Hardin: Paying Producers for Fat and Solids-not-Fat in Milk, *Wis. Agri. Expt. Sta. Research Bull. 143* (1942).
196. L. M. Lampert: The Phosphatase Test and Its Application to Cheese, *J. Dairy Sci.*, **28**, 751 (1945).
197. G. P. Sanders and O. S. Sager: Modification of the Phosphatase Test Applied to Cheese and Application of the Test to Fluid Milk, *J. Dairy Sci.*, **29**, 737 (1946).
198. L. M. Lampert: The Freezing Point of Milk, *J. Assoc. Off. Agri. Chem.*, **22**, 768–771 (1939).
199. A. W. Turner: Digestibility of Milk as Affected by Various Type 3 of Treatment, *Food Research*, **10**, 52 (1945).
200. H. H. Sommer: *Theory and Practice of Ice Cream Making*, published by the author, Madison, Wis.
201. R. J. Block and Diana Bolling: *The Amino Acid Composition of Proteins and Foods*, Springfield, Ill., Charles C. Thomas, 1945.
202. M. B. Williamson: The Amino Acid Composition of Human Milk Proteins, *J. Biol. Chem.*, **156**, 47 (1944).
203. I. M. Kolthoff and H. A. Laitinin: *pH and Electro-Titrations*, New York, John Wiley and Sons, Inc., 1941.
204. U. S. Dept. Agri.: *Agricultural Statistics*, Washington, D. C., (1945).
205. California Crop and Livestock Reporting Service: *Special Publication 216* (1946).
206. T. R. Pirtle: *Handbook of Dairy Statistics*, U. S. Dept. Agri., 1933.
207. E. G. Misner: Methods Used in Determining Basic Milk Prices and Butterfat Price Differentials, *Cornell Univ. Agri. Expt. Sta. A.E. 488* (1944).
208. M. S. Schechter, M. A. Pogorelskin and H. L. Haller: Colorimetric Determination of DDT in Milk and Fatty Materials, *Ind. Eng. Chem.*, **19**, 51 (1947).
209. C. K. Johns: Studies Comparing the Sanitizing Efficiency of Hypochlorites and Quaternary Ammonium Compounds, *Can. J. Research, Sec. F*, **25**, 76 (1947).
210. C. G. Grulee, H. W. Sanford and P. H. Herron: Breast and Artificial Feeding, *J. Am. Med. Assoc.*, **103**, 735 (1934).

The following publications are of special interest to those who wish detailed information on the bacteriology and chemistry of milk and dairy products, as well as on their manufacture, composition, nutritive value and testing.

1. Associates of Lore A. Rogers, *Fundamentals of Dairy Science*, 2nd. ed., New York, Reinhold Publishing Corp., 1935.

2. B. W. Hammer, *Dairy Bacteriology,* 2nd. ed., New York, John Wiley and Sons, Inc., 1938.

3. E. H. Eckles, W. B. Coombs and H. Macy, *Milk and Milk Products,* New York, McGraw-Hill, Inc.

4. H. H. Sommer, *Market-Milk and Its Related Products,* Madison, Wis., Published by the Author, 1946.

5. C. L. Roadhouse and J. L. Henderson, *The Market-Milk Industry,* New York, McGraw-Hill, Inc., 1942.

6. W. L. Davis, *The Chemistry of Milk,* London, Chapman and Hall, Ltd., 1939.

7. C. C. Tolman, G. L. McKay and C. Karsen, *Butter,* New York, John Wiley and Sons, Inc., 1939.

8. O. F. Hunziker, *Condensed Milk and Milk Powder,* La Grange, Ill., The Author, 1946.

9. J. L. Sammis, *Cheese Making,* Madison, Wis., 1942.

10. Doane, Lawman and Matheson, *Cheese Varieties,* U. S. Dept. of Agriculture Bull. 608, Washington, D. C.

11. H. H. Sommer, *Theory and Practice of Ice Cream Making,* Madison, Wis., The Author, 1938.

12. American Public Health Assoc., *Standard Methods of Milk Analysis,* New York, 1947.

13. International Association of Milk Dealers, *Laboratory Manual,* Chicago, Ill., 1933.

14. H. C. Sherman, *Chemistry of Food and Nutrition,* New York, Macmillan Co., 1941.

15. E. V. McCollum, E. Orent-Keiles and H. G. Day, *The Newer Knowledge of Nutrition,* New York, Macmillan Co., 1939.

16. W. H. Eddy, *What Are the Vitamins,* New York, Reinhold Publishing Corp., 1941.

17. E. P. Daniel and H. E. Munsell, *Vitamin Content of Foods,* Misc. Pub. 275, U. S. Dept. Agriculture, Washington, D. C.

18. R. A. Gortner, *Outlines of Biochemistry,* New York, John Wiley and Sons, Inc., 1938.

19. U. S. Dept. of Agriculture, *Food and Life,* Yearbook, 1939.

20. American Dairy Science Association, *Journal of Dairy Science.*

21. *Journal of Milk Technology,* Albany, N. Y.

22. *Journal of Dairy Research,* Cambridge, England, University Press.

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